Report to Congress on Implementation of DoD ManTech Projects Receiving FY03 - 05 Funds

Under Secretary of Defense
Acquisition Technology and Logistics

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Implementation of DoD ManTech Projects Receiving FY03 – 05 Funds

Report to Congress

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EXECUTIVE SUMMARY

This report is written in response to the National Defense Authorization Act for Fiscal Year 2008, Public Law 110-181 (January 28, 2008), Division A - Department of Defense Authorizations, Title II - Research, Development, Test and Evaluation, Subtitle D- Other Matters, section 234 - Report on Implementation of Manufacturing Technology Program, which states:

"*Not later than September 1, 2008, the Secretary of Defense shall submit to the Committee on Armed Services of the Senate and the Committee on Armed Services of the House of Representatives a report on the implementation of the technologies and processes developed under the Manufacturing Technology Program required by section 2521 of title 10, United States Code.*"

This report includes over 100 implementations of manufacturing technologies and processes developed with funds appropriated or otherwise made available for the Manufacturing Technology programs of the military departments and Defense Agencies for fiscal years 2003 through 2005. These implementations enabled the use of new Warfighter technologies, provided more affordable manufacturing processes, and achieved rapid and economical repair of critical systems and components. ManTech funding for individual projects ranged from $200K to over $10M. Many of these efforts resulted in major cost avoidance in the acquisition of military equipment.

Some examples of manufacturing technologies and processes that were successfully implemented include the following: affordable MEMS-based Inertial Measurement Units (IMUs); military apparel manufacturing supply chain process improvements; C-17 main landing gear composite doors; laser shock peening techniques for increased durability of Army and Air Force propulsion systems; laser additive manufacturing processes to repair aircraft components; a composite overwrap process for lightweight cannons; improved Lithium-Ion energy storage systems for SEAL Delivery Vehicles and Future Combat Systems; new manufacturing processes to reduce cost of the Large Aircraft Infrared Countermeasures Systems; and non-destructive inspection techniques for F100 and F110 engine components.

This report is organized in accordance with the structure of the Joint Defense Manufacturing Technology Panel Sub-panels and, hence, the main body of the report (Sections 2 through 5) is categorized by electronics, metals, composites, and other manufacturing technologies and processes. "Implementation", as defined by section 234 means the use of a technology or process in the manufacture of defense materiel; the inclusion of a technology or process in the systems engineering plan for a program of record; or the use of a technology or process for the manufacture of a commercial item. A conclusion in Section 6 is followed by two appendices: Appendix A summarizes the type of implementation that was achieved for each process and/or technology described in Sections 2 through 5 of this report; Appendix B contains a list of acronyms.

Implementation of DoD ManTech Projects Receiving FY03 – FY05 Funds

Report to Congress
September 2008

1 OVERVIEW

1.1 INTRODUCTION

The Manufacturing Technology (ManTech) Program was established by Congress by Section 2521 of Title 10, United States Code:

"….to further national security objectives through the development and application of advanced manufacturing technologies and processes that will reduce the acquisition and supportability costs of defense weapon systems and reduce manufacturing and repair cycle times across the life cycles of such systems".

The ManTech Program draws on innovation created throughout the science and technology base, works with the defense manufacturing industrial base, military S&T and weapon systems communities, sustainment and logistics organizations, academia, and focuses on defense use of commercial technology. The Program is conducted with a wide range of organizations, including prime contractors, subcontractors, suppliers, hardware and software vendors, industrial consortia, manufacturing centers of excellence, colleges and universities, and research institutes. It also includes close collaboration with the Services, Defense Logistics Agency (DLA), Missile Defense Agency (MDA), the Department of Commerce (DoC), the Department of Energy (DoE), the National Science Foundation (NSF), and the Department of Homeland Security (DHS).

The Office of the Secretary of Defense (OSD) ManTech Program is managed by the Office of the Deputy Under Secretary of Defense for Advanced Systems and Concepts (ODUSD (AS&C)), which has oversight of the ManTech programs executed by the Army, Navy, Air Force, and DLA. All of these components collaborate on a regular basis through the Joint Defense Manufacturing Technology Panel (JDMTP). The JDMTP operates under a charter signed by the Director Defense Research and Engineering (DDR&E) and the S&T Executives of the Army, Navy, Air Force, and DLA. The JDMTP is responsible for coordinating programs on advanced manufacturing technologies and processes and developing joint strategies for the ManTech programs of the Army, Navy, Air Force, and DLA. The specific ManTech projects of the Services and DLA are coordinated with JDMTP through its Sub-panels – Electronics, Metals, and Composites – in order to identify opportunities for joint coordination and to prevent duplication of effort.

This report is organized in accordance with the structure of the JDMTP sub-panels and hence, the main body of the report (Sections 2 through 5) is categorized by Electronics, Metals, Composites, and Other Manufacturing Technologies and Processes.

1.2 PURPOSE OF REPORT

This report is written in response to the National Defense Authorization Act for Fiscal Year 2008, Public Law 110-181 (January 28, 2008), Division A - Department of Defense Authorizations, Title II - Research, Development, Test and Evaluation, Subtitle D - Other Matters, section 234 - Report on Implementation of Manufacturing Technology Program, which states:

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This report includes manufacturing technologies and processes developed with funds appropriated or otherwise made available for the ManTech programs of the military departments and Defense Agencies for fiscal years 2003 through 2005. It includes a description of Army, Navy, Air Force, and DLA ManTech projects that were completed and the technology or process successfully implemented or ongoing for which the technology or process is included in the systems engineering plan for a program of record. The individual project descriptions include the following elements required by section 234:

1. the project of the ManTech program through which the technology or process was developed, the participants in that project, and the duration of the project;
2. the organization or program implementing the technology or process, and a description of the implementation;
3. the total ManTech funding or other DoD funding required to implement the technology or process;
4. the total value of industry cost share (if applicable);
5. the total value of cost avoidance or cost savings directly attributable to the implementation of the technology or process, if appropriate; and/or
6. a description of system performance enhancements, technology performance enhancements, or improvements in a manufacturing readiness level of a system or a technology.

"Implementation", as defined in the Public Law 110-181 language, refers to the use of a technology or process in the manufacture of defense materiel; the inclusion of a technology or process in the systems engineering plan for a program of record; and/or the use of a technology or process for the manufacture of a commercial item.

1.3 HIGHLIGHTS OF PROJECTS IMPLEMENTED

Over 100 implemented manufacturing processes or technologies are described in this document. These projects provided more affordable manufacturing processes, enabled the use of new Warfighter technologies, and effectively transitioned technology, including rapid and economical repair of critical systems and components. ManTech funding for individual projects ranged from $200K to over $10M. Many of these efforts

resulted in major cost avoidance in the acquisition of military equipment. The many successful implementations demonstrated the major benefits of the ManTech Program in responding to the needs of the defense community. A summary of implementations described in each section is highlighted below:

<u>Electronics – Packaging, Assembly, and Obsolescence:</u> Coordinated tri-service efforts enabled the implementation of more affordable Micro Electro-Mechanical System (MEMS) inertial measurement units. This resulted in new missile and munitions designs that were previously unachievable. ManTech also implemented commercial parts obsolescence tools to reduce life cycle costs.

<u>Electronics – Electro-Optics:</u> ManTech investments in Focal Plane Array technologies enabled higher yields, lower costs, and faster transition of sensor technology to the Warfighter. Specific products include thermal weapons sights, driver vision enhancement systems, pilot night vision, and missile detection.

<u>Electronics – Power:</u> Major advancements were made in transitioning Lithium Ion battery manufacturing processes. This enabled implementation of higher power, longer duration batteries for Future Combat System and SEAL delivery vehicles.

<u>Metals – Processing:</u> A number of successful efforts focused on metal surface technologies, to include Laser Shock Peening, corrosion protection, superfinishing and reshaping. Metals affordability projects furthered the use of laser additive manufacturing, net shaping, roll forming, and electron beam technology.

<u>Metals – Joining:</u> New capabilities that were demonstrated include friction stir welding of aluminum and titanium; weld distortion, accuracy and process control; and a new ultra-light welding system. A single-melt process for titanium enabled joining of plate material on Army, Navy, and Air Force platforms.

<u>Metals – Modeling and Simulation:</u> Implementation of computer-aided design and manufacturing systems enabled reduced lead-time and affordability in maritime construction planning, sequencing, facility optimization, and fabrication.

<u>Metals – Inspection and Test:</u> The implementation of advanced non-destructive (ultra-sonic) inspection techniques in current and future generation aircraft engines permitted safe life extension of engine components for seven to ten years of additional service. Improved structural alignment and gear metrology processes were implemented in submarines.

<u>Composites and Lightweight Materials:</u> Composites manufacturing technology improvements permitted the substitution of composites for metals to provide lower weight and reduced life-cycle cost. Advanced composites were implemented in the Future Combat Systems, Expeditionary Fighting Vehicle, C-17, DDG 1000, and helicopters.

<u>Lean Manufacturing:</u> A number of ManTech Lean efforts were employed to reduce cycle-time in Air Logistics Centers, provide added surge capability for Joint Direct Attack Munition production, and improve the effectiveness of DLA’s Industrial Plant Equipment operations.

<u>Troop Support:</u> The implementation of automation and end-to-end supply chain tools enabled the merging of wholesale and retail inventories, leading to the successful transition of recruit depot military apparel operations to DLA. Numerous combat ration improvement efforts enabled higher quality, safer, affordable, and surge-capable production.

ManTech for Depots: ManTech implemented model-based manufacturing tools and automated environmentally-friendly processes at depots and Air Logistics Centers. These implementations improved throughput for vehicles and aircraft and helped meet operational maintenance surge requirements.

Energetics and Munitions: ManTech addressed high rate production surge requirements for the Joint Programmable Fuze, and implemented affordable insensitive munitions and explosive processes.

The next four sections – Electronics, Metals, Composites, and Other Manufacturing Technologies and Processes – provide a comprehensive description over 100 implementations. Section 2 includes over 30 electronics project implementations in the areas of packaging, assembly, and parts obsolescence; electro-optics; and power. Section 3 provides summaries of 48 projects in the metals technology areas of processing, joining, modeling and simulation, and inspection and test. Composites materials technology project implementation summaries are presented in Section 4. Section 5 provides summaries of other manufacturing technology implementations in. the areas of Lean manufacturing; troop support; advanced ManTech for depots; and energetics and munitions. Appendix A consists of a table that summarizes the type of implementation achieved for each one of the projects. Appendix B contains a list of acronyms.

2 ELECTRONICS TECHNOLOGIES AND PROCESSES

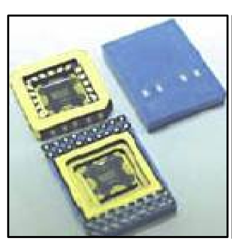
2.1 Electronics – Packaging, Assembly and Obsolescence

2.1.1 Reduced Cost Micro Electro-Mechanical System (MEMS)-Based Inertial Measurement Units for Military Applications Overview

Inertial Measurement Units (IMUs) are one of the most expensive components in guided missiles and munitions. The Army, Navy, and Air Force have jointly conducted efforts to develop and demonstrate an affordable high-rate manufacturing process to enable sufficient defense material manufacture of tactical grade MEMS IMUs. The implementation of lower cost manufacturing of MEMS sharply reduces IMU cost, physical size, and power consumption. MEMS-based IMUs offer significant advantages due to increased reliability and reduced cost, size, weight and power thus expanding product applicability across multiple implementing programs and further reducing cost through economy-of-scale. The Service ManTech investments have made it feasible to realize the cost benefits of using MEMS and have opened the door to new missile and projectile designs that were either physically unachievable with conventional technology or that were simply unaffordable. A description of the individual Service applications for MEMS-based IMUs is found below.

2.1.1.1 Army MEMS Applications

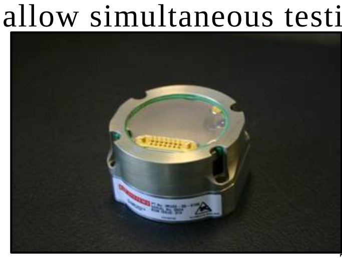
Army transformation goals require systems that are lighter, faster and more lethal. Manufacturing of low-cost, high-G, high-accuracy MEMS IMUs in precision munitions have helped meet those goals. The IMUs have been implemented and are operational in Iraq and Afghanistan as part of the Excalibur 155mm precision artillery warhead.



They are also on track to be integrated into Hellfire Missiles and the Mid-Range-Munitions. This project reduced the cost of MEMS-based IMUs through inspection, testing, packaging, and process control configurations with less labor touch time, and process control enhancements and improved yields. The project duration was from 2001-2008. Participants included the U.S. Army Research Development and Engineering Command (RDECOM) Armaments Research, Development, and Engineering Center (ARDEC) (Picatinny Arsenal, NJ), Aviation and Missile Research, Development and Engineering Center (AMRDEC) (Redstone Arsenal, AL) and Honeywell (Minneapolis, MN). The project used $34.1M of Army ManTech, $100.2M of Army S&T funding. Industry cost share was $55.7M. As a result of this project, the IMU cost was reduced from $15.6K per unit to $6.5K per unit. Further refinements are expected to bring the cost down to $1.5K per unit for a total cost benefit of $850M across Army systems.

2.1.1.2 Navy MEMS Applications

Munitions that use MEMS technology offer increased accuracy and result in a greater percentage of enemy targets destroyed and less chance of collateral damage. Extending the precision guidance capability of MEMS technology to munitions fired from Navy ships allows precision strikes on enemy targets within the range of the shoreline. The Navy MEMS project implemented manufacturing processes to improve throughput time and reduce manufacturing cost. A MEMS-sensor test station was established along with a sensor ion beam trim station at a single location; a rate table was also established to allow simultaneous testing of multiple IMUs. In addition, the project provided the



Navy with an additional competitive IMU supplier from which to choose the best IMU product for its Extended Range Guided Munitions (ERGM) program. The MEMS IMUs are planned to be implemented in the Advanced Gun System and Long Range Land Attack Projectile (AGS-LRLAP) in the first quarter of 2011. BAE Systems – a commercial supplier of MEMS-based accelerometers – successfully manufactured a SiIMU02 IMU (at <4 in^3) that contains three low cost, COTS MEMS-based accelerometers. The project duration was from September 2002 - December 2006. The Navy Electronics Manufacturing Productivity Facility (EMPF) coordinated its MEMS effort with the U.S. Army-Picatinny Arsenal, U.S. Army-Redstone Arsenal, and the U.S Air Force Research Laboratory. Other participants included L-3/Interstate Electronics Corp., BAE Systems Inertial Products (U.K.), and Raytheon Electronic Systems (Dallas, TX). The total Navy ManTech funding was $3.92M.

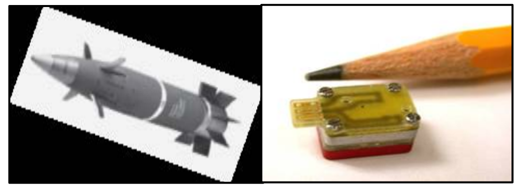
2.1.1.3 Air Force MEMS Applications

Improved MEMS-based IMUs enable increased missile and munition lethality with reduced collateral damage, and a smaller IMU package enables the design of smaller guided weapons to meet future Warfighter needs. Honeywell (Minneapolis, MN) worked with the Air Force Research Lab (AFRL) to successfully develop manufacturing methods to lower the cost and size of MEMS-based IMUs. Automated testing was implemented to be able to handle multiple tests at once and larger parts counts per test. In addition, processing methods were developed to screen sensors at the chip level before assembly in order to build IMUs using matched components to meet the overall system accuracy requirements and reduce scrap. Some of the programs to fully implement improved MEMS-based IMU production process improvements include: Joint Direct Attack Munition (JDAM), Wind-Corrected Munitions Dispenser (WCMD), Joint Air-to-Surface Standoff Missile (JASSM), GPS-Aided Munition (GAM), Range Pods, Enhanced Guided Bomb Unit (EGBU-15), E-Paceway 3, AGM-130 (Air-to-Ground Missile), Joint Strike Fighter (JSF), Miniature Air Launched Decoy (MALD),

and the NetFires Precision Attack Missile (PAM). The project duration was from April 2002 - April 2005. The total Air Force ManTech funding was $5.6M. Other DoD funding used to co-develop the manufacturing process improvements totaled $8.5M. Honeywell provided cost sharing in the amount of $5.23M.

2.1.2 MEMS Implementation on Fuze Safe-and-Arm Devices

Another MEMS application is munitions fuzes. The Army conducted a project using an improved process to fabricate metal MEMS-based Safe-and-Arm (S&A) devices. These MEMS-based devices enable safe arming of the warhead after firing. Metal is used in order to survive the severe gun-launch environment. The Army ManTech effort successfully demonstrated improved fabrication processes, explosive loading technologies, and an affordable and repeatable assembly method. They are planned to be available as a drop-in replacement for the Artillery Precision Guided Kit, Increment 2 during FY09, and in the MK19 and M203 grenade launchers during FY11. The project duration was from October 2004 –August 2007. Participants included the Army RDECOM ARDEC (Picatinny Arsenal, NJ), Axsun Technologies (Billerica, MA) and Alliant Techsystems (Plymouth, MN). The total Army ManTech funding was $12.5M with $8.5M cost share from PM Soldier Weapons for fuze integration and testing. The total cost avoidance is expected to be $33.5M.

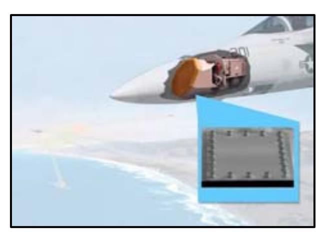


2.1.3 Affordable Ferroelectric and MEMS-Based Phase Shifters for Phased Arrays

The Army pursued technologies to meet transformation goals of a lighter, faster, more lethal force with integrated on-the-move communications from sensor to shooter. Phased arrays provide the means to achieve high data rate on-the-move communications, but are expensive to produce. This project improved the producibility and manufacturability of ferroelectric and MEMS-based wafers and devices. As a result of this ManTech project, the phase shifter cost was reduced from $50 to $10 for the estimated million-plus production quantities. This manufacturing technology was implemented through an Army technology transition agreement with the WIN-T Increment 3 acquisition program. The technology is planned to transition to the Advanced Missile Technology ATO during FY09 for application to the Non Line Of Sight (NLOS) and Surface Launched Advanced Medium Range Air to Air Missile (SLAMRAAM) systems. The project duration was from October 2004 – August 2007. Participants included the RDECOM Communications Research, Development and Engineering Center (CERDEC), Agile RF, Inc. (Goleta, CA) and the Raytheon Space & Airborne Systems Advanced Products Center (Dallas, TX). The total Army ManTech funding was $13.4M. The return on investment is projected at 13.3 to 1 with a cost benefit of $134M.

2.1.4 Bump Attachment Process Enables MMIC Flip-Chip Technology

As a result of Navy ManTech efforts, low cost Monolithic Microwave Integrated Circuit (MMIC) flip-chip device throughput issues have been resolved and they are now readily available. They are now being incorporated into the transmit/receive (T/R) modules of the Active Electronically Scanned Array (AESA) Radar in F/A-18 E/F Aircraft. The two RF bumped-die fabricators – Raytheon and TriQuint – worked with the Navy PMA-265 Program Office to



F/A-18 AESA Radar using die with Flip-Chip bumps

implement MMIC Flip-Chip technology in 2006. Raytheon Engineering Development Labs prototyped the bump attachment process that inserted silver-bumped MMICs into T/R module production and migrated this technology into their Production Fabrication Facility. Overall enhancements include increased space and 60% reduced weight in the F/A-18 from the reduced size of the radar components. A three-fold increase in production throughput and transfer to commercial fabrication houses ensures the needed manufacturing volume for F/A-18 production. Project duration was from 2002 – 2005 and participants included the Electronics Manufacturing Productivity Facility (EMPF)(Philadelphia, PA), PMA-265 F/A-18 Program Office, Raytheon (El Segundo, CA), TriQuint Semiconductor (Richardson, TX), Raytheon RF Components (Andover, MA) and M/A COM (Roanoke, VA). The total Navy ManTech funding was $3.534M with industry cost sharing of $6.044M. Expected cost reduction for flip-chip devices utilizing this new bump technique will result in a projected savings of $220 per channel over 42 systems for a total of $24.7M. Implementation is also planned for the F-15 and F-16 aircraft.

2.1.5 Masking and Demasking Process Improvements for the AESA Radar

The Active Electronically Scanned Array (AESA) radar is solid state radar that operates with an extremely fast scanning rate, much higher range, lower probability of intercept, and better reliability than conventional radar. Masking and demasking process problems have plagued AESA radars, preventing their adoption into weapons systems because of their previously high cost. As a result of this Air Force ManTech project, they are now a viable alternative to conventional radars. Manufacturing process improvements were first implemented by Northrop Grumman in 2007 when masking and demasking process improvements were integrated into their production lines for the F-22A and F-35. In this project, Air Force ManTech worked with contractors and sub-tier vendors to reduce the costs by maturing the processes and manufacturability of AESA materials and components. A redesigned circulator and housing stick reduced the amount of touch labor. Redesigning the radio frequency (RF) manifold reduced the cycle time by four weeks. Finally, a switch from gold plating to silver lowered the overall cost of the T/R modules. This project also upgraded Raytheon's production test capability from one module to one hundred modules at a time. The project duration is from FY03 to FY09. Participants include the Air Force ManTech Program office, Northrop Grumman (Baltimore, MD), and Raytheon (El Segundo, CA). The total Air Force ManTech funding for this project is $18.5M. Over $200M in cost avoidance is projected for the F-22A and F-35.

AN/APG-77 (AESA) Radar

2.1.6 Hermetic Sealing of SiC Wafers for T/R Modules on Phased Array Radars

Near-hermetic seals of Silicon Carbide (SiC) wafers are required to replace traditional radio frequency (RF) hermetic packages that are bulky and expensive. Navy ManTech, in partnership with the Navy Small Business Innovative Research Program and Sundew Technologies, evaluated Dow Corning's state-of-the-art advanced coating capability. Title III funds were secured to apply the wafer scale coating technology to MMIC transmit/receive (T/R) modules that will transition to the DDG 1000 multi-function phased array radar system in 2010. The planned near-hermetic coating process represents significant cost and weight advantages over traditional ceramic packaging and is actively being pursued on other defense programs. The resulting module can operate throughout radar and communications equipment lifetimes without failure.

Implementation of this technology will reduce radar T/R module cost by 25%. The project duration was from November 2004 to September 2006. Participants included the EMPF (Philadelphia, PA), Dow Corning (Midland, MI), Raytheon (Tewksbury, MA), and Sundew Technologies (Broomfield, CO). The total Navy ManTech funding was $2M. Raytheon provided internal funds to purchase manufacturing level coating equipment for production of the DDG 1000 T/R modules. With thousands of T/R modules per radar, the potential cost avoidance is over $1.5M per radar.

2.1.7 Flexible Display Manufacturing Technology for Soldiers

Fragile glass-based displays must be ruggedized for Warfighter environments, which dramatically increase the weight for the system. Soldiers require situational awareness in daylight, night, and adverse weather. They need equipment with flexible displays that are lighter weight, lower power, and more rugged. The Army ManTech Flexible Display Initiative project established an integrated pilot line and processes to manufacture affordable full-color active matrix displays. These novel flexible displays are being integrated into system demonstrators to provide the Warfighter with sensor data and reliable, lightweight communications, and situational awareness. Implementation occurred through creation of commercial manufacturing materials and toolset products; the project is on track for full development of a pilot-line compatible process that will meet military demands. DuPont Teijin Films commercialized a high performance, high surface quality plastic substrate material, and Honeywell Electronic Materials is producing a flexible and low temperature display material. EVG commercialized a large area thin film coater manufacturing tool that has been purchased by a company for flexible display manufacturing. Flexible display panels were integrated into the Soldier Flex Personal Data Assistant demonstrated in the Army's Future Force Warrior Advanced Technology Demonstration in 2007. A technology transition agreement with Program Executive Office (PEO) Soldier for full implementation is on track for FY09. The duration of this project is from FY05 – FY09, and participants include the Army Research Laboratory (ARL) (Adelphi, MD) and the Flexible Display Center at Arizona State University (with 21 industry partners, including the U.S. Display Consortium, now FlexTech Alliance). This project leverages $29.8M S&T funding and $49.4M of funding from Arizona State University and the industry partner contributions. The total Army ManTech funding is $22.5M.

2.1.8 Improved Processes Result in Reduced Costs for LAIRCM Systems

Large aircraft are vulnerable to attack by Man Portable infrared missiles. The Large Aircraft Infrared Countermeasures (LAIRCM) system offered protection, but fielding of capability was limited by the industrial base that could not meet DoD's production demand and cost target. The countermeasure system automatically detects a missile launch, determines if it is a threat, and activates a high-intensity directed laser beam to track and defeat the threat. In the LAIRCM project, Air Force ManTech worked with its contractor, Northrop Grumman, to successfully reduce the manufacturing costs of the Viper™ Laser. Lean

practices and principles were implemented in July 2005 that improved production yield and increased the production rate from 2 to 15-20 per month. This reduction in acquisition cost now makes it financially feasible to acquire more LAIRCM systems and protect more aircraft. Also, because the program enables the contractor to ramp up production more quickly, installation schedules were accelerated by one year, enough time to allow LAIRCM to protect C-17s, C-130s, MH-53, and the CV-22 during Operation Iraqi Freedom. This project was conducted from April 2002 – March 2005 and participants included the Air Force ManTech office and Northrop Grumman (Rolling Meadows, IL). The total Air Force ManTech funding was $5.6M, and Northrop Grumman provided industry cost share funds of $4.3M. Significant cost saving procedures implemented in the manufacture and assembly of the Viper™ Laser decreased the overall LAIRCM acquisition cost per aircraft from $1.8M to $1.2M per system.

2.1.9 Improved High Voltage Packaging Reduces Weight and Improves Reliability

Current iron and copper transformers used in legacy shipboard power distribution systems are heavy, oversized, and unreliable. New Wide Band-Gap (WBG) semiconductor materials, principally SiC, offer the necessary materials properties to address the higher power performance challenges. This Navy ManTech project, *Manufacturing and Packaging of Power Systems for DDG 1000 and Carriers*, developed and demonstrated the reliability of high voltage packaging processes to allow operation of SiC electronic components at the higher temperatures required for the Solid State Power Substation on the CVN 21. This SiC packaging effort successfully demonstrated a low temperature silver die attach with high thermal conductivity and developed a SiC device package for operation at 200° C and 20 kV isolation which will be used in the CVN 80 Class of ships under a Memorandum of Understanding between DARPA, ONR, and PEO Carriers. Use of SiC power conversion on Navy ships will reduce the current conversion equipment size by approximately 60% and weight by 2.68 tons for each converter. Power conversion equipment developed using SiC technology is projected to significantly reduce the workload and maintenance requirements for current and future carriers and is considered a critical step in achieving CVN 21 compliance with key performance parameters for weight reduction and ship stability. This project was conducted from October 2005 – August 2006, and participants included the EMPF (Philadelphia, PA), Virginia Institute of Technology (Blacksburg, VA), Penn State University (State College, PA), Powerex Inc. (Youngwood, PA), Northrop Grumman (Baltimore, MD), and Cree Inc. (Durham, NC). The total Navy ManTech funding was $301K.

2.1.10 Lead-Free Manufacturing Guidelines for the F/A-18

Worldwide requirements mandating lead-free solder processes can adversely impact system costs and reliability. This Navy ManTech project developed and documented a manufacturing process guideline to address this issue for high reliability applications of avionics on the F/A-18 and electronic components on the AEGIS weapons system. This program provided the U.S. Navy with specific manufacturing guidelines for aerospace and military applications thus reducing the learning curve associated with introducing new soldering technologies and mitigating implementation risk and schedule impact. The project developed a specific process for manufacturing F/A-18 Integrated Defensive Electronic Countermeasures (IDECM) modules and the F/A-18 Head-up Display (HUD) modules. An F/A-18 IDECM Service Replaceable Assembly (ITTP/N 2682584) was built using lead-free and mixed solders/finishes, and was successfully tested using the same tests as tin-lead based assemblies. Two guidebooks were published in 2006, the *Lead-Free Soldering Standard (ACI-081906)* and the *Lead-Free Manufacturing Guidelines*. This project was conducted from February 2005 – August

2006 and participants included the EMPF (Philadelphia, PA), F/A-18 Program Office (Patuxent River, MD), PEO AEGIS (Washington, DC), Boeing, Rockwell Collins (Cedar Rapids, IA), ITT Avionics (Clifton, NJ), and Lockheed Martin. The total Navy ManTech funding was $1.127M.

2.1.11 Improved Output Traveling Wave Tube Manufacturing Processes

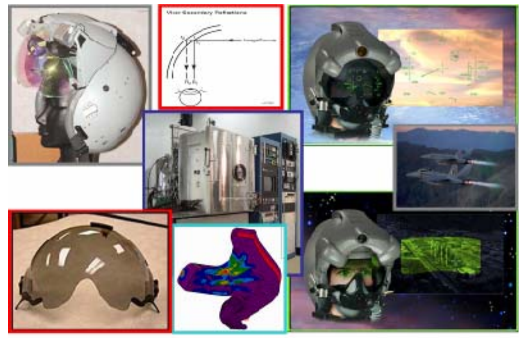
Low yields on Band 4 Jammers drove up the costs on Output Traveling Wave Tubes (OTWTs). Improved manufacturing and packaging processes for OTWTs are now in operation at the L-3 Communications plant in San Carlos, CA. This Navy ManTech project, *Manufacturability of Output Traveling Wave Tubes for Jammer Applications,* implemented factory improvements including a higher quality e-gun assembly, electron beam welding equipment, and an automated helix insertion machine. The project achieved increased Band 4 jammer yields and demonstrated packaging and manufacturing improvements for advanced OTWT replacements. The improved OTWTs were implemented in 2007 on AN/ALQ-99 on the Navy EA-6B. This project was conducted from January 2005 to March 2006 and participants included the EMPF, PMA-234 (for EA-6B), Naval Surface Warfare Center (Crane, IN), L-3 Communications (San Carlos, CA), and Teledyne (Rancho Cordova, CA). The total Navy ManTech funding was $501K. Cost savings include reduced material costs of 35% and reduced labor costs of 45%.

2.1.12 Improved Surge Capability for Night Vision Goggle Intensifier Tubes

Surge requirements for night vision goggles could not be met by existing industrial base capability. The *Integrated Panoramic Night Vision Goggles Program* successfully matured a second source for 16 millimeter image intensifier tubes for the existing night vision goggles. This Air Force ManTech project successfully implemented manufacturing process improvements that reduced the process steps, amount of touch labor and delivery costs; improved the intensifer tube production yield; and achieved Manufacturing Readiness Level 6 (able to manufacture/prototype in a production-relevant environment). This project ensured there will be sufficient surge capability to handle any future Warfighter demand for 16 mm image intensifier tubes. Special operations units received the first shipment of improved Panoramic Night Vision Goggles in April 2005 for use by C-130 and MC-130 Combat Talon aircrews. This project was conducted from 2002 - 2003 and participants included the Air Force ManTech office and Northrop Grumman, Corp. (Rolling Meadows, IL). The total Air Force ManTech funding was $1.3M.

2.1.13 Improved Manufacturing Processes for Helmet Mounted Display Visors

Manufacturing processes for older composite visor retention tangs were labor-intensive. This Navy ManTech project, *Helmet Mounted Display Visor Manufacturing Process,* produced a more cost-effective injection-molded thermoplastic tang design for the helmet-mounted display visors (HMDV) which was implemented in the F/A-18 and JSF in 2007. This effort reduced unit production cycle time, cost and improved the overall reliability of the HMDVs. System performance enhancements include a four-fold reduction of the visor secondary reflection intensity from greater than 2% to less than 1%, an advanced beam-splitter design, and a more rugged hard



Helmet Mounted Display Visor Manufacturing Technology

coat layer protection to prevent scuffs and scratches. This project was conducted from February 2005 to September 2007 and participants included the Navy ManTech Program's Electro-Optics Center (EOC), the Naval Air Systems Command (NAVAIR) F/A-18 Program Office, and Rockwell Collins. The total Navy ManTech funding was $2.3M. The cost savings for the F/A-18 alone are expected to be $36M.

2.1.14 New Littoral Combat Ship Flexible Antenna System Reduces Interference Problems

Increased mission flexibility requires more antennas which increases interference and coupling problems on the Littoral Combat Ship (LCS). This Navy ManTech project, *LCS Flexible Antenna* System, developed solutions for reducing the number of antennas on the LCS deck to decrease their interference and maintain adequate co-site performance. This will also allow interchangeable mission packages to be swapped out pier side in a matter of hours. This flexible antenna system is planned to be prototyped and installed on the LCS in 2009. The installation will take place at BAE and General Dynamics, Bath Iron Works (Bath, ME). This project was conducted from March 2005 – January 2006, and participants included the EMPF, PMS-501, PEO-C41, and Rockwell Collins. The total Navy ManTech funding was $686K.

2.1.15 Processes and Tools to Predict and Manage Electronic Parts Obsolescence

Parts obsolescence for both new and legacy weapon systems was a growing problem due to aging military systems and no contractor incentive to produce limited quantity supplies for military-unique parts. This problem impacted mission readiness and cost the government millions of dollars every year. The *Electronics Parts Obsolescence Initiative (EPOI)*, managed by the Air Force ManTech Program, introduced production management processes and tools to predict and proactively manage electronic parts obsolescence. In 2003, Northrop Grumman (Baltimore, MD) successfully completed the first of two pilot EPOI demonstration programs. They integrated a number of proactive practices, procedures and commercially-available tools into their mainstream business practices and obtained large cost reductions. In July 2004 Lockheed Martin (Orlando, FL) completed a second obsolescence management effort that documented cost savings. Today, Lockheed uses these tools corporate-wide in the design and production of weapons systems. This project was conducted from 2000 – 2004. The total Air Force ManTech funding was $11.2M.   The cost savings is greater than $22M to date.

2.2 Electronics – Electro-Optics

2.2.1 Improved Yield and Advanced Fabrication Technology for Night Vision Systems

Soldiers require improved night vision systems to meet operational needs, but the costs of the uncooled Focal Plane Arrays (FPAs) have been prohibitively high. The Army ManTech *Uncooled Infrared Focal Plane Array (IRFPA) Producibility* project improved the affordability of these high resolution (640x480) uncooled IR sensors. The project enabled the implementation of advanced fabrication technology and an improvement in yield. Implementation took place in 2005 on the Thermal Weapons Sight, Driver Vision Enhancer, and Stryker Remote Weapon Station Uncooled B-Kit. This project was conducted from October 2003 – September 2006 and participants included RDECOM CERDEC Night Vision Electronics Sensors Directorate (Ft. Belvoir, VA), PM Night Vision/Reconnaissance, Surveillance and Acquisition (Ft. Belvoir, VA), Raytheon Vision

Systems (Goleta, CA), DRS IR Technology (Dallas, TX), and BAE Systems (Lexington, MA). The total Army ManTech funding was $15.4M. The cost per FPA was reduced from $9K/unit to $2K/unit. With an annual production rate of 12,000 FPAs per year, the total cost avoidance is projected at $936M.

2.2.2 Two-Color Mid-Wave IRFPAs Increase Warfighter Survivability

Improved, low cost IRFPAs are needed to provide increased survivability across multiple platforms. The Navy ManTech Program funded several projects – *Advanced IRFPA Manufacturing Technology and the Two-Color Mid-Wave IRFPA Manufacturing Process Implementation* – through the Navy ManTech Program's EOC that implemented a two-color mid-wave six-inch process at two IRFPA manufacturing facilities. These projects reduced IRFPA unit costs from $200K to $15K. Higher IRFPA yields translated into lower cost sensor systems, making the threat warning system more affordable and available to multiple platforms. In 2006, Raytheon successfully demonstrated their triple layer heterojunction two-color IRFPA at higher yield and lower cost. In addition, DRS worked with PMA-272 to successfully implement its two-color IRFPAs in the 3rd quarter of 2007 on the F/A-18 D/E and F/A-18 E/F. These projects were conducted from March 2001 – February 2006 and participants included the Navy EOC (Freeport, PA), the Naval Research Lab, PMA-272 (for implementation on the F/A-18), Raytheon, and DRS Technologies. The total Navy ManTech funding was $13.3M. DRS also provided cost sharing in the amount of $1.2M. This represents a total cost savings of $631M.

2.2.3 Large Scale Wafers Reduce Costs of JSF Infrared Focal Plane Arrays

Because of cluster defects, IRFPAs did not meet Air Force system requirements to provide critical image data to the Warfighter. Additionally, low yields caused high unit costs and in the past have accounted for 75% of the total cost of the F-35 Infrared Detector Assembly system. Air Force ManTech worked with the F-35 Joint Program Office and its contractors to implement affordable and reliable IRFPAs. As a result of the *Joint Strike Fighter Infrared Focal Plane Array (IRFPA) Program*, the Air Force developed larger-scale Indium Antimonide (InSb) wafers with reduced cluster defects and transitioned them into the F-35 Infrared Detector System. This project lowered the cost of IRFPAs by implementing manufacturing process improvements to include automated materials handling and inspection to reduce defects and breakage. FLIR Indigo Operations increased the IRFPA yield of its production line from 47% to 78% passing yield with decreased cluster defects. This project achieved MRL 8 (low rate production readiness). Cincinnati Electronics bought capital equipment to produce larger scale wafers which leads to increased production yield (e.g., more IRFPAs per wafer) at the same labor cost for an overall lower cost per wafer. This project was conducted from April 2003 – June 2005, and participants included the Air Force ManTech office, FLIR Indigo Operations (Santa Barbara, CA), Cincinnati Electronics (Cincinnati, OH), and Anteon (Dayton, OH). The total Air Force ManTech funding was $2.419M. Additional DoD funding of $2.73M was provided to co-develop the improved IRFPAs. The Air Force achieved its goal to produce four-inch diameter InSb wafers and achieved a direct cost avoidance of about $400 million in the F-35 JSF Program.

2.2.4 Manufacturing Improvements Reduce Cost of Dual Band Focal Plane Arrays

FCS requirements for long range threat identification necessitated a new generation of night vision capability. This Army ManTech project, *Dual Band Focal Plane Array*

Manufacturing, reduced the cost of the 3rd Generation IR focal plane arrays from $705K to $17K (small format arrays) and from $1.6M to $60K (large format arrays). The lower cost enabled full development of 3rd Generation IR systems and implementation into FCS and other systems such as the Long Range Advanced Scout Surveillance System (LRAS3). Implementation is planned through a technology transition agreement for 3rd Generation IR in FCS during FY10. The Army Forward Looking Infrared program manager is implementing a system level technology demonstration enabled by this manufacturing technology project. This project was conducted from FY03 – FY06 and participants included the Army RDECOM CERDEC Night Vision Electronic Sensors Directorate, Raytheon Vision Systems (Goleta, CA), and Rockwell Scientific Co (Camarillo, CA). The total Army ManTech funding was $51.3M with $19.5M of industry cost share. This project has a projected cost avoidance of $298M.

2.2.5 Reduced Cost Manufacturing and Improved Large Spinel Windows for JSF

Magnesium aluminate spinel windows are preferred over sapphire windows because they transmit further into the infrared spectrum, allow greater detection distances, and provide better infrared threat/target detection discrimination capability during high-speed, air-to-air encounters. Spinel also is less expensive because it is produced using ceramic powder processes while sapphire needs to be grown in single-crystal form. The spinel technology has the potential to be used in other broad multi-Service applications to include the F-15, Small Diameter Bomb, and Super High Altitude Research Project. The Air Force's *Large Spinel Window ManTech Program* demonstrated that spinel could be made large enough and strong enough to provide a replacement for the current F-35 sapphire windows. The spinel lenses were successfully implemented in 2007. This project was conducted from FY03 – 07, and participants included SURMET Corporation (Burlinton, MA) and Lockheed Martin. The total Air Force ManTech funding was $1.736M, and other DoD funding was provided in the amount of $3.15M. Industry cost share was $1.45M. It is estimated there will be greater than $100M in cost savings when the spinel windows are implemented over multiple platforms.

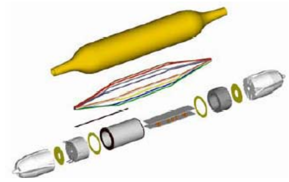
2.2.6 Low cost Fiber Optics Tether Increases Bandwidth on MK48 Torpedo

The old sole source copper wire tether and payout assembly for the MK48 was heavy, bulky, and had limited bandwidth. The new fiber optic tether is lighter, more compact, and provides nearly unlimited bandwidth to the torpedo enabling improvements in range, capability, and lethality. This Navy ManTech project, *Automated Winding Machine for MK48 Torpedo Fiber Optic Guidance Tether*, enabled this transition by reducing the cost of the fiber optic system to be comparable to the cost of the older copper wire payout system. SCI Technologies implemented an automated fiber winding machine used to provide post launch monitoring and command capability in the MK-48 Advanced Capability (ADCAP) torpedo. The MK-48 ADCAP torpedo program office will implement this technology by FY09. The Undersea Weapons Office (PMS 404) is directing the qualification program for introduction of this technology into the fleet. This project was conducted from August 2000 – February 2005, and the participants included the Navy EOC (Freeport, PA), and SCI Technologies (Huntsville, AL). The total Navy ManTech funding was $700K.

2.2.7 New Fiber Optic Array Splice Manufacturing Process for Undersea Array Cables

Fiber optic array electrical splices to integrate the hydrophone to the undersea array cables for the Advanced Deployable System were labor-intensive and unreliable. This Navy ManTech project, *Fiber Optic Array Electrical Splice Manufacturing Process Improvements*, successfully developed the necessary processes to streamline and automate the splices reducing the array fabrication time and providing a reliable watertight assembly. Raytheon Naval and Maritime Systems implemented the

automated process in 2006. The new process reduces the touch labor costs by 68% and improves the yield and survivability of the array. This project was conducted from February 2001 – September 2003 and participants were the Navy EOC (Freeport, PA), PMS 183 (Advanced Deployable System Program Office), Raytheon Naval and Maritime Systems, Penn State University Applied Research Laboratory. The total Navy ManTech funding was $1.847M. Cost savings are projected to be $9.65M for 1,000 units.

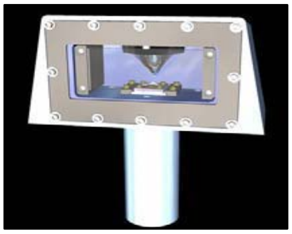


2.2.8 Automated Fiber Optic Interconnect Technology Process

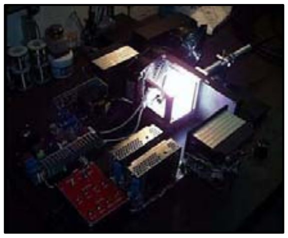
Fabrication of fiber-optic interconnects was difficult, labor intensive, error-prone and costly for the F/A-18. The purpose of this Navy ManTech project was to automate the fiber optic termination process, to increase fiber optic system reliability, and to minimize operator intervention and error in the manufacture of the fiber optic interconnects. Ksaria, Inc. (Lawrence, MA) in partnership with Lockheed Martin successfully automated what had been a difficult and time-consuming manual process by introducing automation into the termination process for the manufacture of fiber optic interconnects. The Ksaria automated fiber-connector assembly and test system was implemented in the 2nd quarter of 2006. This Navy ManTech project was conducted from August 2001- February 2006, and participants included the Navy EOC (Freeport, PA), Lockheed Martin (Newtown, PA, Eagan MN, Fort Worth, TX, and Denver, CO), NAVAIR PMA-272 (F/A-18 Program Office), and Ksaria Inc, (Waltham, MA). The total Navy ManTech funding was $3.2M. A breakeven point on the investment due to labor savings is expected in less than five years.

2.2.9 Alternate Remote Shipboard Lighting for Reduced Costs

Traditional direct lighting systems in shipboard applications have had maintenance, and life cycle cost issues. NGS conducted an initial demonstration on the DDG 78 to validate the RSL concept for shipboard lighting and its advantages over the conventional lighting system (e.g., point-to-point wiring that uses a diversity of lamp assemblies that generates considerable maintenance requirements for spare parts and personnel to install them). This Navy ManTech project successfully developed a lighting system that includes rugged, flexible, low cost fiber (with low losses across the visible spectrum), improved cabling of the fiber, and the development of efficient coupling to low cost, long life, high intensity light sources. As a result of this Navy ManTech project, remote source lighting (RSL) systems are now replacing both Mast head and task lights on the LPD 17. This technology was implemented in 2003. This project was conducted from October 2000 – May 2003, and participants included Navy EOC (Freeport, PA), Navy PMS 400, Northrop Grumman Shipbuilding (Pascagoula, MS), Polymicro Technologies, (Phoenix, AZ), Draka Cableteq, USA, (North Dighton, MA), RSL Fiber Systems, (Salem, NJ), and Omni Technologies, Inc (New Orleans, LA). The total Navy ManTech funding was $812K. Industry cost share was provided in the amount of $860K. The cost savings are expected to be $2.7M ($300K per hull on 9 hulls) due to the reduction in life cycle costs related to maintenance and logistics.



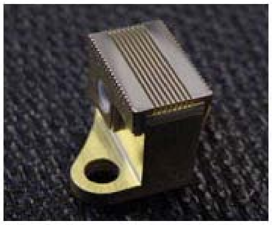
Waterline Security Light



Illumination Source

2.2.10 ManTech for Military Lasers

New eye safe laser rangefinders were required with reduced size, weight and cost for Army Future Force systems. This Army ManTech project improved the manufacturing processes used to produce laser diode arrays in two specific wavelengths required by the Army. The first was for the Apache Laser Rangefinder/Designator and the second was for the Heat Capacity Laser. This project successfully delivered "Butterfly" packages for testing, and implemented automated wafer thinning, automated bar stacking and statistical process control (SPC) techniques to reduce the cost and improve the manufacturing throughput of the laser diode arrays. This technology was implemented on the Apache Helicopter in 2005. This project was conducted from FY03 – FY05, and participants included RDECOM CERDEC Night Vision Electronic Sensors Directorate, Axcel Photonics (Marlborough, MA) and Coherent, Inc. (Denver, CO). The total Army ManTech funding was $4M. Industry provided cost sharing in the amount of $1.4M. Projected cost avoidance is $30M based on 124,000 laser diode bars for the Apache.



2.3 Electronics – Power

2.3.1 Lithium-Ion Battery Cost Reduction and Military Implementation Efforts

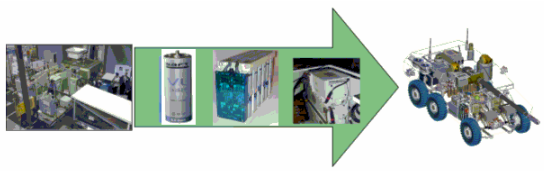
Lithium Ion (Li-Ion) batteries provide the Warfighter with higher power and energy density, but are expensive to manufacture. By leveraging consumer electronic and commercial energy storage advancements of the lithium-ion (Li-Ion) battery industry, Army and Navy ManTech successfully laid the groundwork for advancing the manufacturing capability to ensure a domestic source of Li-Ion batteries for military use. The Navy met the challenge to safely and economically package Li-Ion batteries and battery monitoring electronics to withstand the rugged environmental conditions encountered in Special Operations missions. The Army is working to reduce the cost and improve the manufacturing of high power Li-Ion batteries for use in the FCS System of Systems Development and Demonstration Vehicle. The Air Force plans to use lower cost, higher reliability Li-Ion batteries for the JSF. Two highlights of the Navy and Army programs that have implemented Li-Ion battery technology are found below.

2.3.1.1 New Energy Storage System for SEAL Delivery Vehicle

The maintenance workload associated with electrolyte-filled batteries diverts Navy SEALs from their mission. Lithium Ion energy storage systems last longer and thereby requires less maintenance. The acquisition cost of the Li-Ion energy storage system is higher than that of the silver-zinc; however, the cycle life greatly overcomes the higher cost. The Navy developed the SEAL Delivery Vehicle (SDV) energy storage system to replace the existing silver-zinc (AgZn) systems. The SDV energy storage system offers the following Warfighter enhancements: increased mission capability with extended battery cycle-life – seventeen times that of the existing AgZn battery; one-time installation of a Li-ion battery system during FY08/09 matches ideally with

the expected service-life of the MK8 MOD1 SDV (FY2015); reduced life cycle costs (mainly due to less maintenance); and a charge-in-place feature for faster turn-around time by eliminating removal from the vehicle and transfer to the forward torpedo room. Working with Saft America, the Navy ManTech Program's EMPF developed a replacement Li-Ion energy storage system for the MK8 Mod 1 SEAL Delivery Vehicle (SDV) that was deployed in 2007 by the Naval Surface Warfare Center, Panama City. As a result of this project, Navy SEALs are able to better conduct special operations missions with the new improved system that requires no activation, no clean-up, and no purge. The system arrives activated and ready for charge. The project was conducted from September 2003 – January 2007, and participants included the EMPF (Philadelphia, PA), PMS-Naval Special Warfare (NSW), Saft America (the battery manufacturer and system integrator), Naval Surface Warfare Center – Panama City (for integration of deliverables), and Naval Surface Warfare Center Crane (for safety testing of electronics modules). The total Navy ManTech funding was $1.2M. Cost savings are expected to be $18M over 12 years mainly due to the elimination of maintenance.

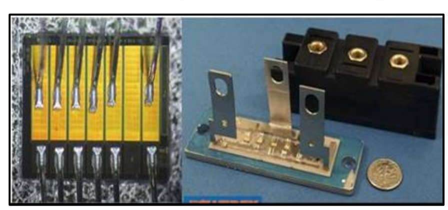
2.3.1.2 Automated Production Line for Very High Power FCS Batteries



Future Combat Systems (FCS) requires hybrid-electric systems powered by Li-Ion batteries to meet their mobility needs. An Army ManTech project demonstrated a state-of-the-art automated production line to produce a vast array of Li-Ion batteries with varying capacities, and a safety and performance improvement of the cell design for improved energy and power density. Saft America successfully reduced the labor hours and at the same time improved the reliability and safety of the high power battery. These Li-Ion batteries were implemented on FCS Systems Development and Demonstration (SDD) prototype vehicles. Improvements have been leveraged by other Services battery products as well. This Army ManTech project was conducted from FY04 – FY09, and participants included the U.S. Army RDECOM Tank and Automotive Research, Development and Engineering Center (TARDEC) and Saft America (Cockeysville, MD). The total Army ManTech funding was $23.6M. The cost of Li-Ion battery packs (for full production) is expected to be reduced from $115K per pack to $58K per pack for total cost avoidance of $121M.

2.3.2 Silicon Carbide Power Electronics Manufacturing for FCS

Semiconductors are a critical element for mobile hybrid electric platforms on the FCS. Current state-of-the-art silicon power switches and high-voltage rectifiers will not operate at the required high-temperature and high frequency to enable size reduction in hybrid electric vehicle traction whereas SiC semiconductors can fulfill the needs of these new platforms. This Army ManTech project demonstrated hybrid electric power components that are building blocks to support an all-SiC traction drive system power module used in FCS ground vehicles. FCS is scheduled to implement reduced cost SiC high voltage diodes and switches in FY09 through a TARDEC and Army Research Laboratory Traction Drive Demonstration. The project duration is from October 2003 - September 2009. Army ManTech participants include Cree Research, Inc (Raleigh, NC) and Northrop-Grumman (Linthicum, MD). The total Army ManTech funds are $28.9M. Industry provided cost sharing in the amount of $8.6M. The projected cost avoidance is $13.6M. Larger cost avoidance would have been realized were it not for the removal of electromagnetic armor from the FCS program.



2.3.3 Thermal Battery Development and Fielding

Thermal batteries are of critical importance to the proper functioning of numerous DoD weapons systems, however, there are limited sources of thermal batteries in the U.S. and unreliable sources overseas. This Navy ManTech project ensured an alternative U.S.-based source for thermal batteries. The project developed a long shelf-life battery for the proximity sensor used in the JDAM, M117, and MK 82 bombs. The batteries were prototyped to meet mechanical, electrical, and environmental requirements for the JDAM and were implemented in 2008. This effort was conducted from June 2005 to December 2006 and included participants from the EMPF (Philadelphia, PA), PMA 201, ATK Power Sources and Enersys (Horsham, PA). The total Navy ManTech funding was $864K. Cost savings were realized in the amount of $2.9M.

3 METALS TECHNOLOGIES AND PROCESSES

3.1 Metals - Processing

3.1.1 Uniform Cannon Tube Reshaping Process

The following military customer quote summarizes the success of this project: *"Barrel reshaping provides the largest improvement in loss-exchange ratio since the introduction of night vision technology" - Colonel Carson, Armor School, Fort Knox, KY.* In 2006, the Army ManTech Program implemented this uniform cannon tube reshaping process at Watervliet Arsenal (NY) in order to greatly improve the accuracy of all tank gun barrels. By achieving a tighter tolerance on the centerline contour, there is a 20-fold improvement in the barrel straightness. This project was conducted from FY00 – FY03. Project participants included ARL, Benet Laboratories, Army Test Center, Army Material Systems Analysis Activity, PM Maneuver Ammunition Systems (MAS), PM Combat Systems, Rock Island Arsenal, Watervliet Arsenal, the Marine Corps, and Automated Dynamics (Schenectedy, NY). The total Army ManTech funding was $7.4M. PM MAS provided funds in the amount of $1.2M. Implementation of this ManTech effort resulted in a 65% reduction in shot group impact dispersion, an improvement in hit probability, thus reducing the total number of rounds needed.

3.1.2 Metals Affordability Initiative – Improved Manufacturing Processes and Accelerated Production of Metallic Components for Aircraft Structures and Engines

This program successfully reduced the costs of manufacturing processes to produce metallic components in aircraft structures and engines by 50% while accelerating the implementation time. The MAI, conducted from 2001 to 2003, focused on lowering costs by reducing the parts count, the inspection time, time-to-market, and life maintenance by improving the yield through modeling of the manufacturing and assembly processes. From 2003 to 2004, several implementations were achieved by numerous program participants including Boeing (St. Louis, MO), Lockheed Martin (Fort Worth, TX), General Electric Aircraft Engines (Evendale, OH), Northrop Grumman (El Segundo, CA), Rolls-Royce (Indianapolis, IN), Honeywell (Dallas, TX), and Howmet Castings (Whitehall, MI). Some examples of implementations are found below:

- Laser Additive Manufacturing was used to repair components on a C-17 pylon panel, on an F-15 pylon fitting, and on the F119 engine, for a potential cost savings of $40M.

- Electron-beam Cold Hearth Melted Slab Ingot technology was applied to the JSF, the F-22, the C-17, and the F-15E for a potential cost savings of $400M over ten years.

- Roll Forming of engine components were applied to the F120, GE90 and GE JSF engines for a potential cost savings of $15M over ten years.

- Forging distortion technology was applied to the F120 engine, and lower cost processing disks were applied to the AE2100 engine.

The total Air Force ManTech funding was $2.2M. DLA added funds in the amount of $8.3M (FY03 - FY0) from the Laser Additive Manufacturing Program. The Army added $577K from the Laser-Engineered Net Shaping Manufacturing Qualification project. Industry cost share was provided in the amount of $1.82M.

3.1.3 Advanced Bonding Methods and Coatings for Steel Structures

This Navy ManTech project is focusing on development and implementation of affordable and improved hull treatment systems and materials for steel ship structures. The emphasis is on the development of a lead-free coverply, durability coatings, manufacturability of the tile body and cover, better paints and adhesives, and alternative seam fillers. To date, the project has resulted in the development of a durable coating that will increase the service life of the system and the alternate materials ease installation labor. This project began in July 2004 and will continue through July 2009. Participants included PMS 500 (Washington, DC), NAVSEA 05 (Washington DC), the Navy Surface Warfare Center - Carderock Division (NSWCCD) (West Bethesda, MD), Bath Iron Works (Bath, ME), Northrop Grumman Shipbuilding (Pascagoula, MS) and the Navy Metalworking Center (NMC) (Johnstown, PA). The total Navy ManTech funding was $5M with an additional $2.1M provided by other DoD sources. Implementation is anticipated in 2009 on the DDG 1000 with a cost avoidance projected at $2.9M per hull.

3.1.4 Collaborative Tools and Technologies Support the Forging Industrial Base

Materials that include forgings have become leading backorder drivers at the Defense Logistics Agency (DLA). This is due to many reasons; hard to find tooling, incomplete technical data, and a lack of forging knowledge bases, among them. The DLA Procurement Readiness Optimization – Forging Advanced Systems Technology (PRO-FAST) Program collaborates with industry to develop and deploy technologies and tools to support the forging industrial base in the production of short run spare part production for the Warfighter. PRO-FAST delivered software, databases, web-based tools, and simulation demonstration tools to address forging supply chain problems. Highlights of FY05-FY07 implementations resulting from FY03-FY05 investments include:

- In FY06, a Production Flow Analysis Simplification Toolkit (PFAST) tool was developed by Ohio State University to assess product flow for a variety of part numbers routed through a job shop. The PFAST is used to successfully design flexible facility layouts that provide a strong foundation for implementing Lean Manufacturing in machining, pipe fabrication, forging, woodworking, cable manufacturing, electronic assembly and welding job shops.

- A PRO-FORGE manufacturing process was installed at Sikorsky Aircraft to improve forging supply design and acquisition from 2004 to 2007. This process solves problematic spare part problems by providing an innovative, teamed approach for addressing both new and legacy forged parts. This led to the replacement of riveted assemblies on the Blackhawk Rebuild program with less costly, more reliable forgings.

- The National Forging Tooling Database (NFTD), a licensed database tool, was concurrently developed and deployed via Haystack Gold to provide Web-access across the DoD industrial network on a daily basis. The NFTD captured over 250,000 line items related to tooling and leverages the DoD's investment of billions of dollars over decades of weapon systems manufacture.

Other federal participants in the PRO-FAST program include the U.S. Army TACOM Life Cycle Management Command, U.S. Army Aviation and Missile Command, U.S. Army Benet Laboratories, Air Force Ogden Air Logistics Center, and the Naval Inventory Control Point - Philadelphia. Non-federal program participants include Ohio State University, Trinity Forge (TX), Bula Forge (OH), Weber Metals (CA), Ulven Forging (OR), Consolidated Industries (CT), Canton Drop Forge (OH), University of Toledo (OH), IHS (CO), Plexus Systems (MI), Scientific Forming Technologies Corporation (OH), General Dynamics (PA, TX), Consolidated Industries, (CT), Sikorsky Aircraft (CT), Forging Industry Association (OH), Colorado School of Mines (CO), Extrude Hone (PA) and RSP Tooling (OH). The total DLA ManTech funding for PRO-FAST was $10M from FY01 to FY08. Industry provided $3.4M of cost share.

3.1.5 National Center for Defense Manufacturing and Machining Products to Support Rapid Response Manufacturing Needs

Defense suppliers have not been able to respond quickly enough to utilize high performance manufacturing materials and processes. The Army ManTech project, *National Center for Defense Manufacturing and Machining* provided training and facilitated the implementation of state-of-the-market manufacturing (machining, cutting, drilling, and grinding), tooling and automated systems. One hundred thirty-three projects have been successfully completed, implementing lower costs solutions to DoD weapons systems. Some highlights of technologies implemented are found below.

- 795 mobile drilling kits were produced and deployed to CONUS and OCONUS locations. These kits provided high-speed/high-torque drills, carbide drill bits, drill sharpener, spare batteries, chargers and a magnetic drill press to provide the rigidity required for armor drilling. Overall HMMWV armor plate drilling times were reduced by 30%, and in some cases, drilling times were reduced from 180 minutes per hole to 6 minutes. The kits helped reduce maintainer fatigue and armored vehicle field repair times.

- Incorporated best manufacturing processes into components of the Excalibur artillery round to reduce set ups from 6 to 3, and cycle time from 7.5 to 1.5 hours, resulting in lower cost, better quality, and increased capacity.

- Upgraded the manufacturing capability at the Redstone Arsenal Prototype Integration Facility to incorporate paperless machining. This reduced the prototype development time for machined parts which improved response time meet Warfighter needs.

The Army ManTech project began in FY03 and is funded through FY08. Participants include NCDMM (Latrobe, PA). The Army ManTech funds (FY03 – FY08) are

$16.8M. The project returned $39.5M in measurable near-term savings and a projected cost avoidance of $470M.

3.1.6 Laser Shock Peening Increases Durability of Army and AF Propulsion Systems

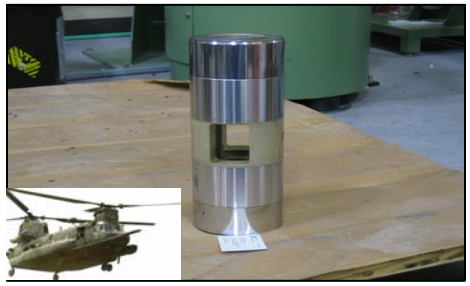
Turbine blade failures result in time-consuming inspections and high maintenance costs. Traditional surface treatment techniques were inefficient in that they removed excess metal and produced an environmental waste stream. Laser Shock Peening (LSP) is an innovative surface treatment technique to increase the durability of titanium turbine engine fan blades and to decrease their sensitivity to foreign object damage from ice and other hard objects ingested into the engine. As a result of the Air Force led *Laser Shock Peening ManTech Program*, General Electric Aircraft Engines (GEAE) used LSP to treat tens of thousands of blades for the F101 engine (B-2) and more than 2,000 blades on the F110 engine (F-16). Pratt and Whitney also expanded LSP applications to integrally-bladed rotors and large components, initially for application in the F119 engine for the F-22 Raptor.   Overall turbine blade failure was reduced, time-consuming inspections eliminated, and maintenance costs lowered as a result of this implentation, which began in 2003. Other systems include the Army's CH-47, UH-60, AH-64 helicopters. The program was conducted from 2000 – 2005, and participants included the Air Force ManTech office, LSP Technologies (Dublin, OH), GEAE (Evendale, OH), Pratt and Whitney (Hartford, CT), and Boeing Corporation (Philadelphia, PA). The Air Force ManTech funding was $9.8M, and Army ManTech funding was $950K. Additional DoD funds were provided to co-develop the technology in the amount of $2.6M. Industry cost share was provided in the amount of $700K. More than $100M was saved due to the implementation of LSP.

3.1.7 Hot Section Coating Protection Technology for DDG 51 Gas Turbine Engine

Gas turbine components operate under severe hot corrosion environments. Extending the life of these components reduces repair frequency and expense. A Navy ManTech collaborative effort with NAVAIR and NAVSEA was conducted to select and screen candidate coating material systems for use on engine components under various temperature regimes and coating classifications. Extending the life of 501-K34 gas turbine engine components under hot corrosive environments was the primary focus. NAVSEA implemented the technology for the DDG 51 501-K34 Gas Turbine Generator at Pratt & Whitney in the Spring of 2007 as a repair technology on stage II blades and vanes. Implementation at NAVAIR is pending the results of comparative testing. This project was conducted from January 2003 - September 2007. Participants were the Institute for Manufacturing and Sustainment Technologies (iMAST) at ARL/Penn State (State College, PA), the NSWCCD (West Bethesda, MD), Naval Surface Warfare Center (Philadelphia, PA), NAVAIR Propulsion and Power Department (Patuxent River, MD), Rolls Royce (Indianapolis, IN and Bristol, England), Chromalloy, Inc. (Orangeburg, NY), Directed Vapor Technologies Inc. (Charlottesville, VA), University of Connecticut (Storrs, CT), Iowa State University Ames Research Laboratory (Ames IA), NASA/Glenn Research Center (Cleveland, OH), TransTech Inc. (Adamstown, MD), Howmet (Indianapolis, IN), and Pratt & Whitney (East Hartford, CT). The total Navy ManTech funding was $1.5M. Industry cost share was $650K. NAVSEA invested $1M in field testing of the repaired engines. Cost savings from the reduction of corrosion is projected at $9.4M over 5 years.

3.1.8 Isotropic Super Finishing Process for Power Transfer Systems

Helicopter transmission gears fail primarily due to pitting, scuffing, contact, or bending fatigue, with each element contributing significantly to the annual maintenance cost for the Army. An Army ManTech project demonstrated (through testing) a novel chemical-mechanical metal surface refinement process known as the REM Chemical, Inc. isotropic super finishing (ISF™). This process, when applied to transmission gears, increased pitting resistance, scuffing resistance, bending fatigue life, and reduced galling. Implementation on the CH-47 Chinook is pending approval of an engineering change proposal at PM Cargo Helicopters. Qualification testing of the tail rotor gearbox for AH-64 Apache is complete, and follow-on testing is planned for the intermediate gearbox. A full qualification program for the UH-60 Black Hawk will be completed in September 2009. CH-47 ISF™ horizontal hinge pins have completed over 800 flight hours at Ft Rucker, with no noted problems. Testing concluded that gears processed using ISF™ perform better than new gears processed without ISF™. PM Cargo, PM Apache, PM Utility are all directly involved in implementation of this ISF process. This project was conducted from FY01–FY03, and participants included the Army RDECOM AMRDEC (Redstone Arsenal, AL), Alion (Chicago, IL), General Electric, Honeywell, Rolls Royce (Evansville, IN), Bell Helicopter (Dallas, TX), Boeing Helicopter (Mesa, AZ), Northstar Gear, Aero Gear, Purdy Gear and Intuitive Research and Technology Corporation (Huntsville, AL). DoD funds used to mature the technology for transition to ManTech was $8.7M. The total Army ManTech funding was $640K. Industry provided cost sharing of $100K.



3.1.9 Improved Magnesium Protection Process for Army Helicopters

Helicopter drive train housings experience very high scrap rates due to corrosion. This Army ManTech project, *Affordable Helicopter Drive Train Housings*, incorporated abrasive cleaning processes and enhanced magnesium corrosion protection systems into overhaul and repair processes for AH-64 Apache drive train components. The processes were implemented at the Boeing Mesa facility on the remanufacturing line for the AH-64 tail rotor gearbox and the intermediate gearbox housings. Several of the MCPP recommendations were incorporated into the depot maintenance repair procedures at the Corpus Christi Army Depot helicopter repair facility. This project was conducted from September 2003 - December 2005. Participants included Army RDECOM AMRDEC, Boeing (Mesa, AZ) and AT&T Government Solutions (Vienna, VA). The total Army ManTech funding was $750K. Over 100 Apache tail rotor and intermediate gear boxes have been returned to service as a result of the repair procedure developed under the MCPP; generating savings and cost avoidance of $10M.

3.1.10 Castings Process Improvements Sustain Legacy Weapons Systems

There is a continuous need for the DoD to be able to depend on a reliable casting supply chain that includes the means to readily locate castings for legacy weapons systems. *The Procurement Readiness Optimization – Advanced Casting Technology (PRO-ACT) Program* led to the implementation of a number of enhancements to the castings industries ability to support DoD systems. Technologies and processes implemented in 2005-06 with FY03-05 funding are:

- An on-line database of the existing Government defense tooling and prime contractor tooling that resides in foundries was used to eliminate the cost of

having to duplicate tooling. In 2006, 275 open procurements had been resolved with a value of over $3.1M by identifying 44 qualified and responsive industry suppliers.

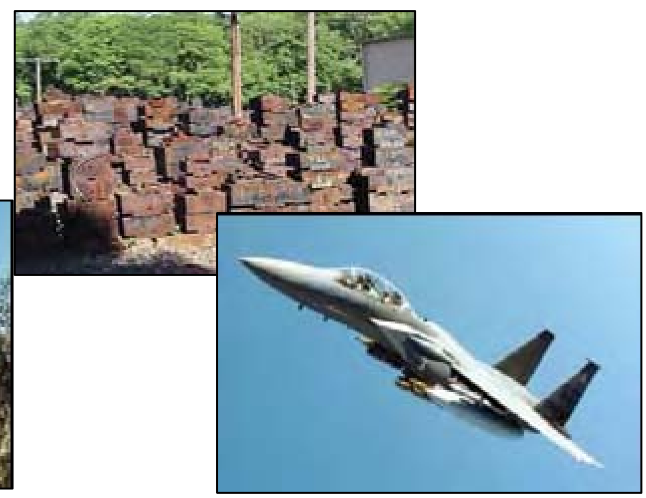
- A Web-based software tool was developed and provided to DLA Supply Center Value Engineers. The tool can estimate and compare the lead times and relative costs of tooling for metal casting applications using different rapid tooling techniques.

- The PRO-ACT program identified new casting sources for selection of material and fabrication methods suitable to facilitate rapid tooling of aluminum die castings for relatively small number of castings (500 – 25,000) and/or prototypes.

This program began in FY01 and has continued through FY08. The American Metalcasting Consortium executes the PRO-ACT program. The consortium consists of the four leading metal casting industry associations – North American Die Casting Association (NADCA), Steel Founders Society of America (SFSA), Non-Ferrous Foundry Society (NFFS), and American Foundry Society (AFS) – industry members, the leading metal casting research universities, DLA, and ATI as the program manager and prime contractor. The total DLA ManTech funding to date is $12.9M, and industry provided $3.1M in cost share. It is estimated there will be a total cost avoidance of $41.7M.

Al Casting Used on Land Systems

Forging Dies Used to Make Parts for F-15



3.1.11 Reconfigurable Tooling Technology for Overhaul and Repair of Aging Subsystems

To ensure affordable repair capability for aging aircraft, Air Force ManTech developed and qualified a production grade, commercial quality reconfigurable tool for sheet metal stretch forming and rapid shape measurement system. WR-ALC continues to realize the benefits of this advanced overhaul and repair capability that enables reverse engineering capability to form aircraft subsystem components with less cycle time and at reduced tooling and labor costs. The project was conducted from FY00 – 04 and implemented at the Warner Robins Air Logistics Center in 2003. Project participants included Northrop Grumman (Los Angeles, CA), Cyril Bath (Monroe, NC), Dimensional Photonics (Wilmington, MA), and MIT (Cambridge, MA). The total Air Force ManTech funding

was $1.7M. WR-ALC provided $4.5M in additional funding to successfully implement the reconfigurable sheet metal stretch forming tool, the measurement system, and other facility modifications.

3.1.12 Single-Melt Process for Titanium in Lightweight Armament and Ground Vehicles

The costs to process titanium have been prohibitively high, making it difficult to be implemented across Army systems. This Army ManTech project demonstrated new processing techniques that lowered the cost of titanium manufacturing. Titanium plates were manufactured using single-melt material developed under the program and made into cupola armor kits for the Striker. The single-melt titanium material developed under this program was applied to Special Operation Command gunner protection kits with planned production of 300 kits. Over 800 cupola armor kits were produced and deployed to Striker Brigades in Iraq. This Army ManTech program met an urgent Warfighter need, and the Army documented that lives were saved as a result. This project was conducted from October 2001 – September 2006, and participants included Army RDECOM ARDEC (Picatinny Arsenal, NJ), BAE (York, PA), Rock Island Arsenal (Rock Island, IL), and the Navy Joining Center (NJC) at Edison Welding Institute (Columbus, OH). The total Army ManTech funding was $10.3M. Cost avoidance was demonstrated at $7 per pound less than the baseline processing costs for a total of $106M in cost avoidance across all systems.

3.1.13 Applications Development for Use of Laser Beam Welded Corrugated Core Panels

Alternate materials and designs for Navy combatant shipboard panels are needed to decrease weight without sacrificing performance in ship structures. Laser Beam Welded Corrugated Core (LASCOR) material was a potential solution to this problem. A Navy ManTech project was initiated to achieve affordable manufacturing of LASCOR panels. The effort included the development of LASCOR as a viable structural material and currently includes incorporating higher strength, more corrosion resistant materials, economical manufacturing of large panels, modular construction techniques and validation of a design manual. Transition of the technology began in 2007. Duplex stainless steel metallic sandwich panels for top side berm and personnel safety barrier panels have been procured for the DDG 1000 with insertion beginning in 2010 with 84 panels per ship. The first two ship-set delivery orders have been issued. Implementation is at Bath Iron Works and Northrop Grumman Shipbuilding. This Navy ManTech project began in March 2004, and is ongoing. Participants include NAVSEA (Washington Navy Yard, DC), NSWCCD (West Bethesda, MD), Northrop Grumman Shipbuilding (Newport News, VA), the iMAST at ARL/Penn State (State College, PA), Applied Thermal Sciences (Sanford, ME), NJC (Columbus, OH) and the NMC (Johnstown, PA). The total Navy ManTech funding is $8.5M. Additionally, $3M was Congressionally-directed to support this activity. The CVN 78 Program Office contributed approximately $300K to support transition.

3.1.14 High Strength Marine Grade Fasteners

Surface ship and submarine components face unique challenges caused by their exposure to harsh marine environments. Of particular concern are the large-diameter fasteners used to attach components on the Seawolf (SSN 21) Class and the VIRGINIA (SSN 774) Class submarines. Corrosion concerns require that the existing fasteners be replaced at periodic intervals to preclude catastrophic failure. This Navy ManTech project identified a material and a manufacturing process that increases the reliability and strength of the fasteners, while reducing life-cycle costs.

This project was conducted from January 2002 – January 2005, and participants included the NMC (Johnstown, PA), Timken Latrobe (Latrobe, PA), SPS Technologies (Jenkintown, PA) and Woodin, Inc. (Bedford Hts., OH). The resulting MP98T fasteners are expected to last for the life of the submarine without mechanical or corrosion failure. The total Navy ManTech funding was $730K. Projected reduced life-cycle costs of $1.1M are anticipated per fielded submarine.

3.1.15 Advanced Thermal Battery Case Production

Thermal batteries used to power sonobuoys, guided munitions, missiles, guidance systems and countermeasure devices were costly, and existing manufacturing processes limited the number of weapon systems that could be purchased. A Navy ManTech project was initiated to improve material utilization, process efficiency and cell component quality. The effort resulted in increased production and improved overall quality of the thermal batteries. Implementation occurred at EaglePicher Technologies in 2002. This project was conducted from September 2000 - September 2003. Participants included NMC (Johnstown, PA), PMA-264 Airborne Anti-Submarine Warfare, Assault and Special Mission Program Office (Patuxent River, MD), the NSWCCD (West Bethesda, MD), EaglePicher Technologies (Joplin, MO) and ENSER Corporation (Pinellas Park, FL). The total Navy ManTech funding was $3.1M. Cost avoidance is estimated at $6.5M, based on cost reduction of $65/battery for 100,000 AN/SSQ-62E active sonobuoys.

3.1.16 Propulsor for Seawolf Class Submarine

Construction of Seawolf Class submarines experience cost and schedule increases due to delays in propulsor manufacturing. The *Propulsor Affordability Initiative* was conducted by Navy ManTech to address affordable manufacturing of the propulsor for the Seawolf Class submarines. High speed machining and processing procedures were demonstrated. These manufacturing technology improvements were transitioned to PEO Subs in November 2002. This technology is also applicable to the VIRGINIA Class submarines (VCS) for manufacture of the VCS propulsor. The project was conducted from October 1999 - November 2002. Participants included the iMAST at ARL/Penn State (State College, PA), NSWCCD (West Bethesda, MD) and PEO Subs (Washington, DC). The total Navy ManTech funding was $2M. Cost avoidance from process improvements and the reduction of critical path delays during manufacture are estimated at $3.4M.

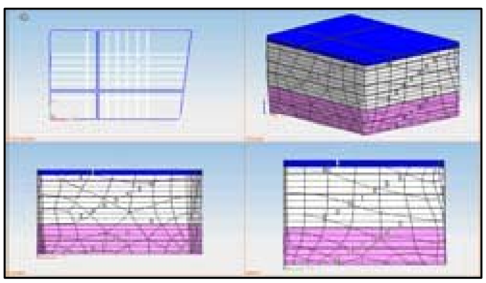
3.1.17 Long Life Non-Skid Coatings for CVN

Non-skid flight deck coatings on carriers must withstand extreme service conditions, including impact, abrasion, exposure to organic fuels and lubricants, and frequent scrubbing or other cleaning processes. As much as 80% of the current non-skid coating must be replaced prior to each deployment. This Navy ManTech project developed a long-life non-skid coating system that should retain non-slip / non-skid effectiveness over multiple (2 or more) deployments. The benefit will be a significant life-cycle cost savings since a single replacement of the coating on a single carrier typically costs $2M to $3M. Qualification testing of the new coating has begun for CVN applications by NAVSEA. This project was conducted from May 2004 – May 2008 at the iMAST at ARL/Penn State (State College, PA). The total Navy ManTech funding was $620K.

3.1.18 Brush Electroplating for Repair of Metal Components

Brush electroplating is commonly used by repair shipyards to conduct in-situ repair of components exhibiting damage due to corrosion, scratches, or wear. Brush electroplating repairs primarily consist of electroplating (depositing) material to build up a damaged surface of a component and refinishing the repaired area to dimensional specification. This Navy ManTech project developed a repair method and automated the electroplating process with subsequent machining to accurately restore valve components to dimensional specification. The technology was transitioned to the Pearl Harbor Naval Shipyard in January 2006 for the Main Ballast Tank Hull Stop Blow Valve brush electroplating repair on SSN 688 Class submarines. This project was conducted from September 2003 - September 2005, and participants included the iMAST at ARL/Penn State (State College, PA), Climax Portable Machine Tools Inc. (Portland, OR), NUWC Keyport (Keyport, WA) and the following Navy shipyards: Pearl Harbor Naval Shipyard (Pearl Harbor, HI), Puget Sound Naval Shipyard (Bremerton, WA), Norfolk Naval Shipyard (Portsmouth, VA), Portsmouth Naval Shipyard (Kittery, ME) and the Kings Bay Naval Base (Kings Bay, GA). The total Navy ManTech funding was $375K. In addition, Pearl Harbor Naval Shipyard provided funding of $140K. Assuming six valve repairs per year at each of the 5 repair facilities results in a cost avoidance of $1.1M over 5 years.

3.1.19 Polycan Fabrication Improvements



During the overhaul of the SSN 688 Class submarines, numerous concentric ring parts called polycans are manufactured. The polycans are welded-together steel and/or aluminum plate material filled with a poly sheet stock. This Navy ManTech project improved the repair and replacement of polycans for submarines. A new approach, implemented at Portsmouth and Pearl Harbor Naval Shipyards during the first quarter of 2006, was established utilizing a Portable Coordinate Measuring Machine, CAD application software called the "Polycan Toolkit", a CNC router, and a commercially available nesting software tool. The new process was validated to show several advantages when compared to the previous manual process. Process time and cost for cutting and fitting the polycan material was reduced by 50%, a 25% material savings due to nesting was achieved, and safety and quality were improved. This project was conducted from May 2002 – August 2005, and participants included the iMAST at ARL/Penn State (State College, PA), Portsmouth Naval Shipyard (Portsmouth, NH), Pearl Harbor Naval Shipyard (Pearl Harbor, HI) and General Dynamics Electric Boat (Quonset Point, RI). The total Navy ManTech funding was $870K and industry provided $200K in cost share. Cost avoidance is $650K per SSN 688 Class submarine and $800K per VIRGINIA Class submarine.

3.1.20 Helicopter Blade Refurbishment

As a result of this Navy ManTech effort, a Laser-based Automated Rotor Blade Stripping System is being made available to replace manual hand-sanding for increased throughput, reduced rework, and reduced cost. The technology provides faster removal of the topcoat while generating significantly less secondary hazardous waste. Real-time sensor feedback ensures that the blades are not damaged during the refurbishment operation. Implementation is on schedule at the

Fleet Readiness Center (FRC) East at Cherry Point, N.C. in FY09. ManTech is leveraging significant industry resources to enable this technology. The project duration is from FY04 – FY09, and participants include the National Center for Manufacturing Sciences (Ann Arbor, MI), Sikorsky Aircraft (Stratford, CT), General Lasertronics (San Jose, CA), FRC East (Cherry Point, NC), NUWC Keyport (Keyport, WA), Koops Robotics (Holland, MI) and the iMAST at ARL/Penn State (State College, PA). The total Navy ManTech funding is $800K; industry cost share is $4.8M. Predicted benefits include reduced emissions for improved environmental and worker health and safety concerns, increased capacity, and significant cost savings (estimated at $0.9M per year) relative to conventional stripping techniques.

3.1.21 Vertical Launch System (VLS) Tube Repair

During pre-deployment weapons load, SSN 688 Class submarines with Vertical Launch System (VLS) capability undergo two NAVSEA required tests – hatch tightness and bubble tests. If the tests fail, the submarine is forced to unload the Tomahawk weapons and transit back to port to undergo emergent brush electroplating of the failed tubes and hatches, an expensive and cumbersome process that often requires 24 hour operation for 3 weeks to repair the tube. This Navy ManTech project is providing an integrated tool to grind, laser clad, and finish repair work of submarine VLS tubes. The system is scheduled for installation at Pearl Harbor Naval Shipyard (PHNSY) during the 3rd quarter of 2008. The benefits of this project include a tenfold reduction in labor hours from about 400 - 500 hours to 40 - 50 hours resulting in improved readiness. The in-situ laser clad process eliminates the use of hazardous materials. This project was conducted from October 2001 – April 2008, and participants included PHNSY (Pearl Harbor, HI), NAVSEA (Washington DC), Naval Undersea Warfare Center (Keyport, WA) and the iMAST at ARL/Penn State (State College, PA). The total Navy ManTech funding was $1.5M with $800K provided by PHNSY.

3.2 Metals – Joining

3.2.1 Availability of Shielded Metal Arc Welding (SMAW) Electrodes for Ballistic Performance Requirements

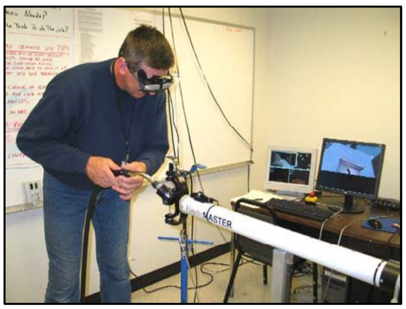
MIL-10718-M electrodes are used for SMAW of HSLA-100 and HY-100 steels on Navy ships. However, the electrode was only available in a 1/8-inch diameter, which tended to yield an unacceptable rejection rate during testing. The results of this Navy ManTech project ensure consistent availability of two diameter sizes of MIL-10718-M electrodes for the cost-effective production of naval vessels. Both sizes have been approved for use in naval weapon systems. The 1/8-inch electrode with ManTech developed production process controls was implemented on the CVN 78 hull and approved for the VIRGINIA Class submarine (VCS) starting in January 2007. The 3/32-inch electrode was approved for use on CVN 21 and VCS in the 4th quarter of 2007. This project was conducted from February 2004 – June 2007, and participants included the PMS 378 Future Aircraft Carriers Program Office (Washington, DC), NAVSEA (Washington, DC), NSWCCD (West Bethesda, MD), Northrop Grumman Shipbuilding (Newport News, VA), General Dynamics Electric Boat (Groton, CT), ESAB Welding & Cutting Products (Hanover, PA), Lincoln Electric Company (Cleveland, OH) and the NMC (Johnstown, PA). The total Navy ManTech funding was $1M.

3.2.2 Low-Cost Friction Stir Welding of Aluminum for LCS Applications

Starting in August 2006, the NMC (Johnstown, PA) worked with the Littoral Combat Ship (LCS) Program Office PMS 501 (Washington, DC), NSWCCD 611 (West Bethesda, MD), American Bureau of Shipping (Houston, TX), Lockheed Martin (Morristown, NJ), Marinette Marine Corp (Marinette, WI), Bollinger Shipyards, Inc. (Lockport, LA), Advanced Joining Technologies (Santa Ana, CA), and Friction Stir Link (Waukesha, WI) to construct a friction stir welding (FSW) machine for the on-site production of thin panel welds on custom panels for the LCS. An operational machine was constructed during the project and will be implemented at the shipyard in 2008. This on-site capability reduces costs and waste using the environmentally friendly solid state FSW welding technology. This $3.1M Navy ManTech project was started with FY05 funds and is planned to end in October 2008.

3.2.3 Virtual Training for Welding

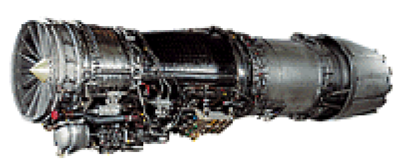
The emphasis on system affordability in Navy ship construction is driving the need for highly skilled welders. This Navy ManTech project developed and demonstrated a



virtual reality system that simulates the gas metal arc welding process (GMAW) as a viable technology to train welders. A virtual reality approach to welder training increases the effectiveness of training, reduces arc time required for training, and significantly reduces material preparation and acquisition costs associated with training. It is estimated that virtual welder training will reduce training costs at GDEB by $81K per year and increase welder productivity by $163K per VIRGINIA Class submarine hull (this represents a 2% productivity increase). Virtual reality training will also result in more highly skilled welders producing higher quality welds with fewer workmanship defects. This effort resulted in a commercially available welding trainer through VRSim and their commercialization partner Silicon Graphics Inc. To date, virtual reality welding simulators have been purchased by Northrop Grumman Shipbuilding Newport News (Navy), Aberdeen Proving Grounds (Army), BAE/United Defense Ground Systems (Army), South Dakota School of Mines and Technology (Army), and the California Penal System. This project was conducted from July 2003 – March 2006, and participants included the NJC at the Edison Welding Institute (Columbus, OH), General Dynamics Electric Boat (GDEB) Division (Groton, CT), VRSim (New Britain, CT), and Silicon Graphics Inc (Mountain View, CA). The total Navy ManTech funding was $670K and industry cost share was $625K. An estimated avoidance of $1.2M is anticipated through FY10.

3.2.4 Translational Friction Welding of Titanium Engine Blisks

GE Aircraft Engines (GEAE), Evendale, OH and the NJC at the Edison Welding Institute (Columbus, OH) conducted a Navy ManTech project that developed a translational friction welding (TFW) process to attach individual airfoils to an engine disk hub for F-18 and JSF engines. GEAE ordered a large multi-million dollar TFW machine to implement this technology on both military and commercial engines. The machine should be fully operational by the end of 2008. Using the TFW process can reduce manufacturing costs and improve the performance of aircraft engines through reduced engine weight, increased high-cycle fatigue life, and increased range due to a reduction in specific fuel consumption. The Navy ManTech funding from July 2001 – January 2008 was $2.6M. GEAE provided $900K industry cost share. The estimated total cost avoidance for fabrication of 1st and 2nd stage engine sets for the



upgraded F414 engine for the F/A-18E/F aircraft is $43M based on a 1000 engine production run.

3.2.5 Manufacturing Large Marine Structures

This Navy ManTech project improved welding technology to reduce the construction cost and enhance the survivability of the DDG 1000 destroyer. *"This new welding process will significantly reduce the cost and cycle time of construction of the PVLS modules." – DDG 1000 Program Manager*. The combination of mechanization and reduced joint volume contributed to a 50% reduction in manual welding, a 25% reduction in welding labor hours, and a 15% increase in first-time weld acceptance. The newly developed mechanized welding procedures and joint configuration have been successfully transferred to Northrop Grumman Shipbuilding and Bath Iron Works. They are the baseline manufacturing process for the Peripheral Vertical Launching

System (PVLS) structures for DDG 1000. This project was conducted from July 2003 – December 2005, and participants included the NJC at the Edison Welding Institute (Columbus, OH), the NMC (Johnstown, PA), Bath Iron Works (Bath, ME), Northrop Grumman Shipbuilding (Pascagoula, MS), NSWCCD (West Bethesda, MD), NAVSEA 03P4 (Washington, DC) and PMS 500 (Washington, DC). The ManTech investment totaled $1.77M. Industry cost share totaled $10.6M. The resulting cost avoidance per hull is $7.75M.

3.2.6 Weld Process Control in Shipbuilding

In order to improve weld quality, reduce weld distortion, and reduce rework on ship structural assemblies for the DDG 1000, Navy ManTech funded the *Weld Process Control Project*. During this project, NGS compared 33 units that were built at the same site for LPD 21 and LPD 22. This resulted in the implementation of the First Time Weld Quality (FTWQ) program at Northrop Grumman Shipbuilding in Pascagoula and Avondale in support of current production of LHD 8, LPD 21, LPD 22, DDG 103, DDG 105, and NSC 2. A total of 91 welders at both shipyards received FTWQ training as part of this project. Based on the success of the program, an additional 140 workers were trained by NGS. After implementation of the FTWQ program, the rework rate was cut in half for LPD 22, as compared to the baseline units for LPD 21. This resulted in a 100% reduction in welding rework labor hours in the piloted area. NGS conducted a similar comparison analysis of 32 units for LPD 20 and LPD 22. Comparing all unit classes, there was a 14.6% reduction in welding labor hours in the piloted areas for those units. This project was conducted from July 2005 – July 2007, and participants included Northrop Grumman Shipbuilding (Pascagoula, MS and Avondale, LA) and the NJC at the Edison Welding Institute (Columbus, OH). The total Navy ManTech funding was $537K.

3.2.7 Weld Distortion and Accuracy Control

Shrinkage and distortion on DDG 51 and LPD 17 structures was a production issue during ship construction. This Navy ManTech project developed techniques to reduce weld distortion. These mitigation techniques which include finite element analysis tools to predict distortion as well as practical welding procedures to control distortion helped the Navy achieve a 20-40% reduction in distortion-related costs. Shipyards originally applied this technology to DDG 51 and LPD 17 Class ships in 2000. Thermal tensioning technology was further developed and implementation is planned at Northrop Grumman Shipbuilding (Avondale) by the end of 2008. This project was conducted from March 1998 – April 2003, and participants included Northrop Grumman Shipbuilding (Newport News, VA, Pascagoula, MS and Avondale, LA), Bath Iron Works (Bath, ME) and the NJC at the Edison Welding Institute (Columbus, OH). The

total Navy ManTech funding was $1.4M. Control of weld distortion resulted in cost avoidance of over $1M on each DDG 51 destroyer to total $21M over five years. These savings result from reduction in fitting time, re-welding time, rework, and flame straightening.

3.2.8 Elimination of Heavy Plate Weld Distortion on CVN 21 Erection Units

Distortion of ship structures due to welding of heavy plates results in assembly and outfitting problems. This Navy ManTech project developed fabrication parameters to produce CVN 21 assemblies that meet flatness requirements and avoid costly and time consuming re-work. Northrop Grumman Shipbuilding (Newport News, VA) incorporated this production process into the Aircraft Carrier Distortion Control Procedure. Project results were applied to first article assembly on CVN 78 as of the 2nd quarter of 2007. Improved weld joint design in the tank top plating will be implemented on all future production units for CVN 78. This project was conducted from February 2004 – August 2007, and participants included PMS 378 Future Carrier Program Office (Washington, DC), NAVSEA (Washington, DC), NSWCCD (West Bethesda, MD), NGS (Newport News, VA), Newport News Industrial (Newport News, VA) and the NMC (Johnstown, PA). The total Navy ManTech funding was $3.6M. In addition, PEO Carriers provided $250K to support this implementation. Northrop Grumman Shipbuilding has agreed to a $140K per hull contract reduction due to the implementation of this process. From a risk reduction and cost avoidance standpoint, the projected cost avoidance is $3M per hull. At seven hulls, the total cost avoidance is $21M.

3.2.9 Ultra-light Welding System

Setup costs for welding operations represent a significant portion of overall shipbuilding costs. For small welding jobs such as pipe hanger and tack welding, the labor associated with equipment relocation and setup can be a large part of the total cost of welding; simple welds that take minutes to perform may take days to set up. To significantly reduce the cost of welding operations, this Navy ManTech project developed a one-man, portable gas metal arc welding unit for shipyard applications. This system eliminates a significant portion of the planning and labor required to relocate and setup welding equipment and improves shipyard safety. This project was conducted from June 2004 – August 2007, and participants were General Dynamics Electric Boat (Groton, CT), Lincoln Electric Corporation (Columbus, OH) and the Center for Naval Shipbuilding Technology (Charleston, SC). Electric Boat implemented three units on the VIRGINIA Class submarine production line in 2008 and plans to purchase up to 25 units by the end of FY08. Northrop Grumman Shipbuilding (Newport News) has shown interest and is evaluating a unit provided by the manufacturer, Lincoln Electric, who is in the process of finalizing the welder for commercial sale. The total Navy ManTech funding was $1.1M with an additional $0.3M provided by the VCS Program to support the implementation. Industry cost share on this project was $1.8M. The compact size allows for ease of use in restricted spaces which results in higher efficiency, higher throughput and a reduction in fabrication costs. The resulting cost reduction is estimated at $0.4M per hull; a total of $12.4M for the projected 31 hulls.

3.2.10 Welding Training and Data Collection

Shipyards face a difficult work force challenge. Skilled structural welders have become more difficult to find and retain. This Navy ManTech project responded to the need to

develop a comprehensive technical and data collection program for structural welders and fitters. The handheld device assists in documenting best practices and providing guidance and training to the work force. The device and associated software has been in use for the LPD 17 at Northrop Grumman Shipbuilding since 2006. The system provides quality performance training, quality performance tracking, daily tasking, and daily status assessment of individual welders. This project was conducted from November 2004 – May 2006 and participants included Northrop Grumman Shipbuilding (Pascagoula, MS) and the Center for Naval Shipbuilding Technology (CNST) (Charleston, SC). The total Navy ManTech funding was $530K.

3.2.11 Implementing High-Strength, Low-Weight Steel on CVN 78

In order to significantly reduce the weight of the CVN 78, a decision was made to implement HSLA-115 steel in lieu of HSLA-100. Navy ManTech invested in four enabling projects, the first of which started in May 2004. Major activities have included optimizing processing and heat treatment, evaluating and analyzing material, ballistic, explosion, mechanical, structural, welding and corrosion properties from slab ingot rolled plate through procurement and evaluation of production steel. The potential total weight reduction from the implementation of HSLA-115 is 100 to 200 long tons per ship. HSLA-115 was formally incorporated into the CVN 78 ship design specifications, and procurement of HSLA-115 construction material for CVN 78 is planned for September 2008. Key participants have included the NMC (Johnstown, PA), the NJC at the Edison Welding Institute (Columbus, OH), Northrop Grumman Shipbuilding (Newport News, VA), NAVSEA (Washington Navy Yard, DC), NSWCCD (West Bethesda, MD), Mittal Steel USA (Coatesville, PA), QuesTek Innovations, LLC (Chicago, IL) and DDL Omni (Vienna, VA). ManTech efforts are planned to continue until February 2010 with total funding of $8.5M. $1M in cost avoidance is estimated by qualifying existing welding processes with HSLA-115.

3.2.12 Improved Welding and Forming Practices for HSLA-65 Materials for CVN 21

The Navy ManTech project, *Concept Exploration for CVN 21*, was initiated to engage the system integrators in the definition of potential future ManTech efforts while addressing near-term metalworking needs for CVN 78. This provided the opportunity to implement technologies that had been developed in the laboratory into the production environment to assess their utility and, as appropriate, to obtain Navy certification for their use in the actual system production. Improved welding and forming practices were developed for HSLA-65 materials which were implemented at the shipyard in 2006 for use on the CVN 21 Class of carriers. This project was conducted from September 2003 – January 2006, and participants included Northrop Grumman Shipbuilding (Newport News, VA), Future Aircraft Carriers Program Office (Washington Navy Yard, DC), NAVSEA (Washington Navy Yard, DC) and the NMC (Johnstown, PA). The total Navy ManTech funding was $2M.

3.2.13 Joint Lightweight Howitzer Manufacturing Technology Implementations

The M777 Howitzer is designed to be air transportable and to meet the increased operational needs of the Marine Corps and Army well into the 21st Century. It is the first 155mm howitzer in the world that weighs less than 9000 pounds and also is the first large-scale use of titanium for ground-based artillery systems.

3.2.13.1 Affordable Titanium Howitzer Components

The Howitzer was too heavy and had too many components. The use of titanium allows fewer part counts and lighter weight. Through the development and implementation of novel manufacturing approaches to reduce the part count as well as innovative forming

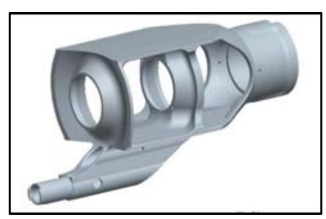
technologies to reduce manufacturing cost and material waste, Navy ManTech improved the affordability of titanium components for the M777 Howitzer. The spades that stabilize the howitzers during firing were previously fabricated by machining and welding 60 individual parts. The part count was reduced to one by producing a near-net-shape spade casting. The howitzer saddle was reduced from a 110-piece sub-component assembly to a single investment cast titanium part. In place of machining-intensive manufacturing processes, the howitzer cradle tube was successfully manufactured using a flow forming and extrusion process. The insertion date for the spade component was achieved for low-rate initial production in October 2003 and for full rate production in the 2nd quarter of 2006. The cradle tubes were delivered in January 2004. The single-piece saddle was also successfully developed and delivered in June 2005 for testing and implementation in Full Rate Production. The project was conducted from July 2002 – May 2006, and the participants included Dynamic Flowform (Billerica, MA), PMF Industries (Williamsport, PA), PCC Structural (Portland, OR), Howmet Castings (Hampton, VA), RTI International (Niles, OH), Titanium Engineers (Stafford, TX) and the NMC (Johnstown, PA). The total investment included Navy ManTech funding of $4.2M, Joint Program Office funding of $250K and industry cost share of $15K. The total cost savings is projected at $37M with $27M resulting from the implementation of the cast spade.

3.2.13.2 Titanium Howitzer Welding

The supporting base structure of the M777 is made from cast and wrought titanium which presents unique welding challenges for both production and in-service field repair. This Navy ManTech project developed consumable titanium inserts to facilitate the use of mechanized welding and designed specialized mechanized welding heads for gas tungsten arc welding of joints as well as a custom plasma arc welding head for butt welds. The welding procedures and fatigue design rules developed during this project were implemented in 2004 by BAE Systems to improve the producibility of the M777 howitzer and permit welded titanium structures to meet performance requirements. This project was conducted from March 2001 – June 2004 by the NJC at the Edison Welding Institute (Columbus, OH). The total Navy ManTech funding was $536K.

3.2.13.3 Steel Investment Castings for Howitzer

To eliminate the welded joint between the howitzer barrel and the muzzle brake, this Navy ManTech project demonstrated manufacturing of a single piece part. Steel casting procedures and processes were developed to improve reliability of the muzzle brakes of the M777 and to provide the muzzle brake and tow bracket as a single cast steel part rather than a welded assembly. This project introduced additional foundries to mitigate supplier risk and developed casting methodologies to improve quality. This project was conducted from July 2005 – November 2007, and participants included MetalTek International (Pevely, MO), Wollaston Alloys (Braintree, MA), Benet Labs (Watervliet, NY) and the NMC (Johnstown, PA). Implementation is anticipated in the 4th quarter of 2008. The total Navy ManTech funding was $970K. Up to $8 million in production cost savings are anticipated with the subsequent purchase of the replacement parts over the lifetime of each gun.

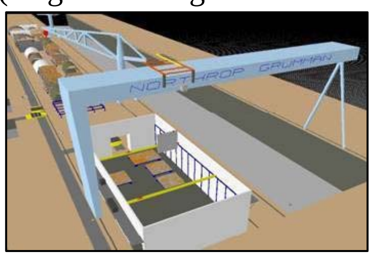


3.2.13.4 Reduced Cost Titanium Alloy for Howitzer

The previous re-melting production method for the M777 left major surface defects that required removal by machining to avoid cracking during the subsequent forging process. This Navy ManTech project developed a single-melt plasma arc cold hearth melting process where the ingot surface finish results in a sufficient quality that it requires little or no surface removal prior to forging. A single-melt titanium forged bell housing that meets performance requirements was demonstrated using the plasma arc cold hearth melting process. This project was conducted from August 2000 – September 2004, and the participants included RTI International Metals, Inc. (Niles, OH), Arcturus Mfg. Co. (Oxnard, CA), Imperial Machine & Tool Co. (Columbia, NJ), and the NMC (Johnstown, PA). The total Navy ManTech funding was $3M. This process provides as much as a 27% reduction in the acquisition cost of Ti-6-4 ingots for the LW155 (lightweight 155 alloy) Program. This Single Melt material process was also used by ARDEC on lightweight Army armament in ground vehicle systems (See 3.1.12).

3.3 Metals - Modeling and Simulation

3.3.1 Modeling and Simulation for Carrier Construction Planning and Sequencing



Construction of an aircraft carrier requires seven years, approximately 160 super lifts (large building blocks constructed and outfitted on the Final Assembly Platen (FAP)), construction of over six hundred base units, and assembly of thousands of details and millions of parts. Construction costs increase as the location of the work moves from the steel production unit, to the platen, to the dry dock, and finally to the pier. The dynamic allocation of FAP space has traditionally proven to be a formidable task for the planners. This Navy ManTech project provided a robust spatial scheduling tool that reduces the manual effort for generating FAP footprints, increases the utilization of FAP space, and allows for rapid generation of alternative footprint plans. The project was conducted from March 2004 – December 2006 by Northrop Grumman Shipbuilding (Newport News, VA) and the iMAST at ARL/Penn State (State College, PA). The spatial scheduling tool has been in use by the Northrop Grumman Shipbuilding planners for CVN 21 since the 1st quarter of 2007 to develop long-range spatial plans for large assemblies requiring large areas of space. The total Navy ManTech funding was $1.1M. The resulting cost avoidance is estimated as $3.9M per hull as a result of a reduction in assembly fixtures, a reduction in lead-time, a reduction of planning labor and the ability to have more building blocks available on the FAP.

3.3.2 Manufacturing Process Modeling and Fabrication for DDG 1000

This Navy ManTech project developed a generic overall shipyard manufacturing process model. This model is then fed information from smaller, component models which are used to define individual processes that make up the overall shipbuilding process. The project developed a standard methodology that defines the architecture and data formats. This project demonstrated the modeling plans and generic interfaces of an actual shipyard manufacturing process. The planning tools enable digital process planning and work instruction generation. The primary benefit is the ability to continually optimize the entire shipbuilding process in the shipyards.

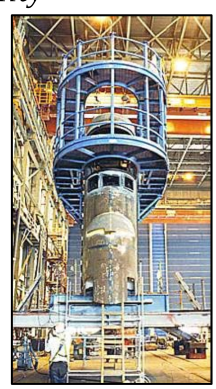
Northrop Grumman Shipbuilding selected and implemented the digital planning environment in the 1st quarter of 2006. Bath Iron Works implemented a pilot application of a digital planning environment during the same year. Other benefits are an increased ability to assess the impact of process changes and the potential for reduced ship production time. This project was conducted from April 2004 – December 2005, and participants included the iMAST at ARL/Penn State (State College, PA), Gulf Coast Region Maritime Technology Center at the University of New Orleans (New Orleans, LA), Northrop Grumman Shipbuilding (Pascagoula, MS) and Bath Iron Works (Bath, ME). The total Navy ManTech funding was $680K.

3.3.3 DDG 1000 Decision Support System for Lead Time Reduction

Shipyard managers need more effective and efficient information to make good decisions. This Navy ManTech project, *Shipyard Simulation – Optimization Decision Support System for Lead-Time Reduction*, designed, developed, and deployed shipyard extended enterprise Decision Support System (DSS) architecture. This enables decision makers to plan and control key resources by analyzing system-wide shipyard behavior through modeling and simulation. In early 2007, Northrop Grumman Shipbuilding (Pascagoula) implemented this technology in the pipe shop enabling live data decision support for DDG 1000 production. The primary benefit is the reduction in lead time by about ten percent. The project was conducted from May 2005 – September 2006, and project participants were the iMAST at ARL/Penn State (State College, PA), the Gulf Coast Region Maritime Technology Center at the University of New Orleans (New Orleans, LA), the Center for Advanced Vehicular Systems (Canton, MS); Department of Industrial Engineering at Mississippi State University (Starkville, MS), and Northrop Grumman Shipbuilding (Pascagoula, MS and Avondale, LA). The total Navy ManTech funding was $1.1M. When fully implemented in the shipyard, the total cost avoidance is projected at $3.6M total.

3.3.4 Reducing VIRGINIA Class Submarine Cost Drivers

Reduced cost is a key driver in Navy shipbuilding. Navy ManTech has been providing manufacturing technology to assist in improving the affordability of the VIRGINIA Class submarine (VCS) with the *VCS Facility Optimization* project. This project provided a robust spatial and schedule planning tool for the Modular Outfitting Facility supporting VCS construction. The computer tool was implemented at the Northrop Grumman Shipbuilding (Newport News, VA) facility in 2007. This project was conducted from December 2004 – March 2007, and participants included the iMAST at ARL/Penn State (State College, PA) and NGS (Newport News, VA). The total Navy ManTech funding was $260K. The benefits of the project include the reduction of non-value added movement of modules as well as a reduction in manufacturing delays caused by space unavailability.



3.3.5 Predictive Weld Distortion Techniques

Flame straightening is often used to remove the distortion caused during the welding process. This labor and time-intensive method is a complicated trial-and-error process that takes years of experience to master. It adversely affects product cost and negatively impacts schedules. The problem is exacerbated by a shortage of skilled labor as age, attrition and outside opportunities reduce the number of welders skilled in

the “art” of flame straightening. By using finite element analysis methods, alternative welding methods can be used to predict methods to reduce the distortion effects. This Navy ManTech project, *Predictive Weld Distortion in Thick Navy Structures*, produced a tool for optimizing thick plate, multi-pass weld joints and processes. Software models are used to predict welding-induced distortion. Weld joints can be optimized to minimize distortion resulting in reduced labor hours and materials. Implementation began in 2007 at Northrop Grumman Shipbuilding in support of the CVN 21. The tool reduces distortion by as much as 35% and uses a mechanized process that deposits 50% more material per pass and reduces the number of structural flips by 50%. The result is 43% less weld volume in reduced welding time. This project was conducted from November 2004 – June 2007, and participants were Northrop Grumman Shipbuilding (Newport News, VA), Battelle Memorial Institute (Columbus, OH), ESI North America (Bloomfield Hills, MI) and the CNST (Charleston, SC). The total Navy ManTech funding was $530K.

3.3.6 Material Workflow Process Improvement for Shipyards

Misplaced or lost material and data in the shipyard creates considerable disruption in the workflow and increases costs by causing a temporary lack of materials, tools, or data at a work station; increased inventory levels; and unplanned reallocation of workers. A project team consisting of Northrop Grumman Shipbuilding (Pascagoula, MS) and the CNST (Charleston, SC) employed Lean management techniques and technologies to develop a total system to resolve this problem. This team developed an internal supply chain best practices tool together with improved material storage and handling procedures. The *Re-engineer Internal Supply Chain* project was conducted from November 2004 – March 2006. The techniques were implemented at Northrop Grumman Shipbuilding (Pascagoula, MS) beginning in 2006 to support LPD 17. The total Navy ManTech funding was $540K. The major benefit is the improved control and deployment of shipyard assets.

3.3.7 VIRGINIA Class Submarine Design Techniques

Making the VIRGINIA Class submarine more affordable is critical to the Navy. Structural fabrication constitutes approximately 20-30% of the costs. To significantly reduce the construction schedule and achieve a step improvement in the cost of major structural units, a new structural fabrication facility was designed that is optimized for fabricating all types and sizes of structural components for the VCS. The *Product Centric Facility Design* project was conducted by General Dynamics Electric Boat (GDEB) with the CNST to improve the fabrication of major submarine sections by re-engineering the structural fabrication processes.

An innovative, semi-automated manufacturing cell for structural shapes was designed, a new manufacturing technique was implemented to automate poly shielding and the Modular Isolated Deck Structure (MIDS) Deck was re-engineered using the part family approach. A process was developed to quickly analyze all the structural data in the CAD system and identify welds that can be completed using robotic welding.

This project was conducted from June 2004 – December 2007, and the participants were General Dynamics Electric Boat (Groton, CT), CNST (Charleston, SC), and iMAST at ARL/Penn State (State College, PA). Implementation at GDEB of manufacturing cells for one of the Major Product Lines (Decks) and two of the Major Part Families (Poly Shielding and Structural Shapes) occurred during 2007. The implementation of the new steel fabrication facility is scheduled for 2012. When fully implemented, the new facility is projected to achieve cost avoidance of between $5M and $9M per submarine; a total of $155M to $279M. The total Navy

ManTech funding was $1.7M. The poly shielding process cost avoidance to date is $0.5M with $3M per hull projected beginning with Hull 781. The re-engineered MIDS deck manufacturing cost avoidance is 30% with a span time reduction of 40% and the structural shapes manufacturing cell is providing a 50% cost avoidance.

3.3.8 Flexible Fixtures Support Product-Centered Structural Fabrication

The Navy ManTech project, *Automated Materials Joining and Flexible Design to Support Product-Centered Structural Fabrication*, developed flexible fixtures and portable welding automation to support product centric manufacturing methods that reduce the cost of families of tanks for the VCS. A trackless mechanized welding system was selected as the appropriate portable welding automation solution. Welding distortion mitigation guidelines were provided and a welding sequence was developed to minimize distortion while maximizing welding productivity. This project was conducted from July 2003 – December 2005, and participants included General Dynamics Electric Boat (Groton, CT), the Institute for Manufacturing and Sustainment Technologies at ARL/Penn State (State College, PA), and the NJC at the Edison Welding Institute (Columbus, OH). GDEB purchased 10 of the trackless portable mechanized welding systems, which have been in use for VCS production since 2007. The welding fixture and welding technology enhancement recommendations are planned to be incorporated into the new product centric steel fabrication facility discussed in 3.3.7 above. The total Navy ManTech funding was $350K.

3.4 Metals - Inspection and Test

3.4.1 Non-destructive Inspection Techniques for F100 and F110 Engine Components

Reducing Air Force sustainment burden for gas turbine engines will free significant resources for other Warfighter priorities. The Air Force is currently using advanced non-destructive inspection techniques in current and future generation engines at the Oklahoma City Air Logistics Center (OC-ALC) that were developed in the *Engine Rotor Life Extension (ERLE)* ManTech Program. ERLE technologies are currently being used every day on the inspection shop floor at OC-ALC, and permit safe life extension of engine components for seven to ten years of additional service.

Air Force ManTech focused on transition of ultrasonic inspection techniques to OC-ALC for F100 and F110 components. ERLE program contractors – General Electric Aircraft Engines (Evendale, OH) and Pratt and Whitney (Hartford, CT) – have both implemented ERLE methodologies as a standard in the analysis of engine disk loading of military airframes. The Manufacturing Readiness Level (MRL) generally increased from MRL 4 to MRL 6+ (e.g., able to be manufactured in a production-relevant environment) during this program. This project is being conducted from FY01 to FY10.

Other ERLE program participants are the Air Force ManTech office, the University of Dayton Research Institute (Dayton, OH), Wyle Laboratories (Dayton, OH), and ISTL (Dayton, OH) (a small business). DoD funds in the amount of $10.1M (from FY01 to FY03) were used to mature the technologies for transition to the ERLE program. The total Air Force ManTech funding was $22.5M, and OC-ALC provided funds in the amount of $2.351M to implement this advanced technology on the remaining inspection systems at the depot. It is

estimated there will be over $300M total cost avoidance by eliminating replacement of multiple components on the F100 and F110 engines and that there will be an additional $250M cost avoidance by extending the life cycle time of both types of engine components. The ERLE program will impact the engine life-cycle cost of the F-15, F-16, B-1, and B-2 fleets.

3.4.2 Submarine Alignments and Inspections

Alignment and Inspection (A&I) tasks are critical for returning a submarine to sea. This Navy ManTech project identified technologies for reducing the time and costs associated with these procedures. A portable coordinate measuring machine and a laser tracker were demonstrated on-site for five application areas at four organic Naval Shipyards (Portsmouth, Pearl Harbor, Norfolk and Puget Sound). The portability and flexibility of these systems allowed the operators to use laptop computers for quick analysis of measured data. Based on these demonstrations, a consensus was reached with the shipyards and resulted in an agreement to implement laser technologies for future alignment and inspection work. The Laser Tracker hardware was acquired by the four shipyards in December 2007. A 50 to 100% decrease in time and cost was demonstrated. This project was conducted from May 2004 – December 2007. The participants were the iMAST at ARL/Penn State (State College, PA), Pearl Harbor Naval Shipyard (Pearl Harbor, HI), Puget Sound Naval Shipyard (Bremerton, WA), Norfolk Naval Shipyard (Portsmouth, VA), and the Portsmouth Naval Shipyard (Kittery, ME). The total Navy ManTech funding was $520K. An additional $700K was provided by the shipyards. The total projected cost avoidance at all four shipyards is about $1M per year.

3.4.3 Gear Metrology and Performance Prediction

Manufacturing errors in meshing gears were causing vibrations that needed to be minimized in a sensitive application. Under this Navy ManTech effort, a specialized

gear measurement method was developed that provides real-time feedback during the manufacturing process. The resulting gear modification recommendations were adopted by PEO Subs for the Seawolf in September 2004. The method was utilized on the system with 100% success. Supporting software and instructions for its use have been transferred to the Navy and a Navy gear vendor. This project was conducted from October 1997 - September 2004, and participants included the iMAST at ARL/Penn State (State College, PA), General Dynamics Electric Boat (Groton, CT) and NAVSEA (Washington, DC). The total Navy ManTech funding was $612K.

4 COMPOSITES TECHNOLOGIES AND PROCESSES

4.1 Composites and Lightweight Materials

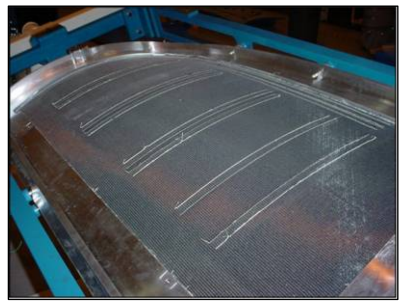
4.1.1 Composites Affordability Initiative: Technologies and Tools for Manufacture of Lower Cost, Large Integrated and Bonded Composite Structures

The Composite Affordability Initiative (CAI), established in 1998, successfully matured technologies and tools for the design and manufacture of lower cost, large integrated

and bonded composite structures across the fixed and rotary-wing defense and commercial industrial base. CAI was a bold and innovative approach to create revolutionary advancements for the design and manufacture of composite aircraft by establishing the confidence to fly large integrated and bonded structures. Some CAI technologies that have been directly implemented are found below:

- In 2005, the Boeing Controlled Atmospheric Pressure Resin Infusion (CAPRI) process was used to make stitched resin-infused preforms to fabricate composite main landing gear doors for the C-17. This technology is estimated to result in $6M cost avoidance by eliminating C-17 main landing gear door repairs and overall is expected to increase the fleet mission capability rate. The technology is now licensed to General Dynamics-Marion Composites for use by industry.

Damaged Main Landing Gear Door



Improved Landing Gear Door Design

- Lockheed Martin and Northrop Grumman developed 3-D woven pi joint and the bonded inlet ducts that have been incorporated into the original JSF design. This enables a smooth interior surface that does not require low observable treatments over fastener holes. The pi preforming technology was licensed to Albany Techweave and is available to other US contractors. Lockheed Martin made additional improvements to the design in order to achieve a cost avoidance estimated to be $600M for the JSF program.

- The CAI team developed uniform manufacturing design standards and processes that are available across the entire industrial base. A series of design handbooks including the *Strain Invariant Failure Theory (SIFT)* have been produced. This was used by Lockheed on the JSF and by Boeing on the F/A-18.

- Since the CAI program ended in 2006, a CAI program database exists that contains mechanical property test data that is traceable back to the process that produced it and lists the processing parameters used as well as the material and its integrity. This interrelationship between materials, processes and performance produces a legacy of data that facilitates the implementation of composite materials and processes in defense material and commercial items manufacturing.

Lockheed Martin plans to implement the Advanced Composite Cargo Aircraft, with the first flight planned for June 2009. Lockheed's concept is for 10% of the parts and 2% of the fasteners of a typical transport aircraft to utilize composite materials. The program's goal is to design, build and fly a militarily-relevant transport aircraft in 17 months for $50M. CAI technologies such as bonded joints are enabling elements of the program. The airframe certification authorities in DoD and the Federal Aviation Administration concurred that bonded composite primary structures are ready for transition.

The CAI team consisted of the Air Force and Navy ManTech Program offices, Boeing (St. Louis, MO and Seattle, WA), Lockheed Martin (Fort Worth, TX and Palmdale,

CA), Northrop Grumman (El Segundo, CA), and Bell Helicopter Textron (Fort Worth, TX). The total ManTech funding for the CAI program, conducted from 1998 to 2006, was $39.4M, and other DoD funding was $16.8M. The total industry cost share was $23.4M.

4.1.2 Composite Overwrap Process for Light Weight Cannons

Future Combat Systems (FCS) requires light weight, high performance materials to meet its size and weight objectives. The Army ManTech *Durable Gun Barrels and Armaments Manufacturing Technologies* project developed and transitioned production-capable large caliber FCS cannon manufacturing processes for composite barrel overwrap used in high performance FCS cannons. The baseline FCS Mounted Combat System 120mm XM360 cannon design incorporated the composite overwrap gun barrel providing over 200 lbs in weight savings. Developmental Electro-magnetic (EM) gun launchers for the Army EM Gun program were produced utilizing the composite overwrap technology as well. This composite technology is transitioned to both the Army and Navy's EM gun programs. Army ManTech participants were the Army RDECOM ARDEC (Picatinny, NJ), Benet Labs (Watervliet Arsenal, NY) and Automated Dynamics (Schenectedy, NY). This project was conducted from December 2003 – February 2007, and the total Army ManTech funding was $16.5M. Cost benefits of this project are projected at $37M.

4.1.3 Low Cost Lightweight Helicopter Structures

Helicopters must carry increasingly larger payloads and perform longer operational missions. In part, this can be accomplished with new lighter weight airframes designed to better match the needs of the military's current operational environment. This Army ManTech project was funded to reduce manufacturing costs, operational costs, and weight in two of the Army's Force Modernization helicopters. The common composite tailcone and composite tailrotor driveshaft are on track for implementation through the Black Hawk (UH-60M) Upgrade production program. In addition, a composite forward pylon for the CH-47 is planned for Boeing implementation on the baseline version of the Air Force variant, and may be adopted by the Army CH-47F. Complex composite structures using novel materials such as X-Cor™ were developed using low cost, solid modeling processes. A primary benefit of the composite tailcone is a weight reduction for the UH-60M upgrade. This program was conducted from October 2003 to September 2007 and the participants included Army RDECOM AMRDEC, Sikorsky Aircraft Corporation (Stratford, CT) and The Boeing Company (Philadelphia, PA). Total Army ManTech funding was $10.3M, with cost share of $4.3M from the implementing PMs. An additional $6.2M was provided by other government programs (e.g., Defense Acquisition Challenge Program) and industry. Projected cost benefits include reduction of UH-60 tailcone annual O&S cost (from $20K to $2K) and CH-47 annual recurring cost (from $142K to $82K).

4.1.4 Extended Life Propulsion Shaft Surface Treatment Process

The surface protection coating applied to Navy propulsion shafts did not provide reliable corrosion protection for more than six to eight years, even though a twelve-year docking cycle was planned for CVN 78 and subsequent carriers. An improved propeller shaft surface treatment process was developed and is now the baseline coating for the CVN 21 program. This new system was successfully demonstrated at the Northrop Grumman Shipbuilding (Newport News, VA) facility. The Program Manager, Future

Carriers Program Office (PMS 378), issued a letter of approval for the new shaft coating system. This project was conducted from October 2002 to March 2007, and the participants included the Composites Manufacturing Technology Center (Anderson, SC); NGS (Newport News, VA); Applied Research Laboratory at Penn State University (State College, PA); NSWCCD (West Bethesda, MD); and NAVSEA PMS 378. The total Navy ManTech funding was $1.498M. The primary benefit resulting from this project is life-cycle cost savings. From data provided by NAVSHIPCO and Norfolk Naval Shipyard (Code 266), the cost savings per year is estimated at $6.1M per year.

4.1.5 Integrated Bleeding Fabrication Process for VIRGINIA Class Submarines

The manufacturing time for steel covers was excessive, averaging three to four months. Under the *Low Cost Submarine Plate Covers* project, Navy ManTech developed a composite integrated bleeding fabrication process and a new low cost tooling approach for the reproducible manufacture of composite dihedral pod door cover plates and countermeasure tube covers for the VIRGINIA Class submarine. Benefits include lower acquisition cost and a reduced schedule. The manufacturing time for composite covers is approximately two to three weeks. This technology is also suitable for rapid back fitting on older Los Angeles, Ohio, and Seawolf Class submarine cover plate doors which need to be replaced. This technology was implemented by both Northrop Grumman Shipbuilding (Newport News, VA) and General Dynamics Electric Boat (Groton, CT) shipyards in 2004 for use on SSN 778 and subsequent hulls. The project was conducted from October 2002 – April 2004, and participants included the Composites Manufacturing Technology Center (Anderson, SC), Northrop Grumman Shipbuilding (Newport News, VA), GDEB (Groton, CT), the Applied Research Laboratory at Penn State University (State College, PA), and NAVSEA PMS 450. The total Navy ManTech funding was approximately $360K with an additional industry cost share of about $86K. The total savings per hull is approximately $600K.

4.1.6 Composite Processes for Expeditionary Fighting Vehicle Troop Ramp Door

The original Expeditionary Fighting Vehicle (EFV) troop ramp assembly was costly ($100,000 per assembly) and heavy (332 lbs). A Navy ManTech project was established to address these issues. The resulting optimized composite EFV troop ramp door was successfully implemented by General Dynamics Land Systems (GDLS) in 2005 and is now part of the baseline design. The new composites door system is completely interchangeable with the original aluminum door. The new composite door weight is 254 pounds for a weight savings of 68 pounds. This project was conducted from August 2002 – June 2005, and participants included the Composites Manufacturing Technology Center (Anderson, SC), GDLS (Lansing, MI), Applied Research Laboratory Penn State University (State College, PA), and NAVSEA PMS 430. The total Navy ManTech funding was $1.1M. An additional $384K was provided as industry cost share by GDLS. This project resulted in a cost savings per vehicle of $13,000 for a total cost savings of approximately $13M across more than 1,000 vehicles expected to be acquired.

4.1.7 New Composite Manufacturing Process for Marine Impeller

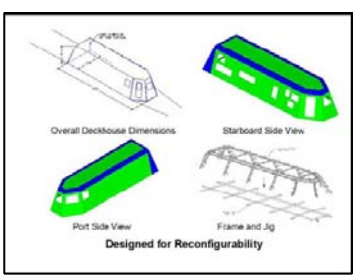
Seawolf and VIRGINIA Class main seawater pump impellers were very costly to manufacture. A new low-cost, close tolerance manufacturing method for composite marine impellers was developed under a Navy ManTech project and implemented at General Dynamics Electric Boat (GDEB) for construction of SSN 780 and follow-on hulls. Delivery time was reduced from ten months to two months. This project was conducted from September 2003 – August 2005, and participants included the Composites Manufacturing Technology Center (Anderson, SC), GDEB (Groton, CT), Northrop Grumman Shipbuilding (Newport News, VA), Applied Research Laboratory Penn State University (State College, PA), and NAVSEA PMS 450. The total Navy ManTech funding was $1.216M. An additional $400K in DoD funds was provided to implement the technology. Cost savings total $220K per impeller with two impellers per hull. The total cost savings for VIRGINIA Class hulls (SSN 780 and follow-on hulls) is expected to total over $12M (over 29 hulls total).

4.1.8 Improved Fabrication Technology for the Advanced Seal Delivery System Stator

The Advanced Seal Delivery System (ASDS) stator experienced issues with cracking. A Navy ManTech project successfully improved the composite fabrication and assembly processes on the stator to eliminate cracking in the assembly and improve structural integrity and stator field performance. The new composite stator was delivered for implementation on ASDS in March 2005. This project was conducted from February 2004 – June 2005 and participants included the Composites Manufacturing Technology Center (Anderson, SC), Applied Research Laboratory Penn State University (State College, PA), and NAVSEA PMS 399. The total Navy ManTech funding was $1.6M. An additional $200K of DoD funds was provided for implementation. Benefits included the elimination of cracking issues as well as a 10 lb reduction in weight at a recurring cost of less than the 120% of baseline target.

4.1.9 Advanced Electric Ship Demonstrator Deckhouse

The Navy is moving toward composite deckhouse structures for future combatant ships in order to reap cost, weight, and signature reduction benefits. A reconfigurable composite deckhouse with interchangeable skin panels was implemented on the test platform for the Office of Naval Research's Advanced Electric Ship Demonstrator (AESD), a platform to test future propulsion and electric drive components. This reconfigurable deckhouse allows for the demonstration of multiple signature reduction techniques as well as manufacturing and integration methods without building a new structure for each test configuration. This project was conducted from December 2004 - November 2005 and participants included the Composites Manufacturing Technology Center (Anderson, SC); Northrop Grumman Shipbuilding (Gulfport, MS); and NAVSEA PMS 500. The Navy ManTech funding was $971K. The composite deckhouse is currently being used for radar cross-section tests on Lake Pend Oreille near Bayview, ID.



4.1.10 Alternate High Frequency Material to Replace Tape Covering Access Panel Gaps and Fasteners on B-2 Aircraft

Tape removal and replacement was the top B-2 maintenance problem. There was a need to remove and replace over 3000 feet of tape per aircraft. A revolutionary high frequency material (AHFM) to replace the tape covering access panel gaps and fasteners on B-2 aircraft was implemented fleet-wide by the Air Force in January 2004. AHFM exposes the gaps and fasteners for easy removal and replacement of the access panels without the requirement of any material restoration afterwards. This effort reduced the material production schedule from 26 weeks to 12 weeks. This project was conducted from 2002 – 2004. The total Air Force ManTech funding was $3.12M. Northrop Grumman provided industry cost share of $170K. This project resulted in a significant increase in aircraft availability and solved the critical material scale-up problem that directly affected the operational availability of the B-2 fleet.

5 OTHER MANUFACTURING TECHNOLOGIES AND PROCESSES

5.1 Lean Manufacturing Overview

Lean manufacturing practices were implemented throughout industry and the military Services and Agencies. Lean principles and practices were first introduced to DoD and the defense industrial base through an Air Force ManTech initiative that began in 1993 when Lean practices were just beginning to be embraced by the US automotive industry. Some examples of Lean principles and manufacturing practices that have been implemented are found below.

5.1.1 Lean Manufacturing Processes for C-17 and F-15

The Air Force ManTech Program's *Lean Aircraft Initiative* has evolved into the current-day *Lean Advancement Initiative (LAI)*. LAI uses Lean principles and practices in aerospace manufacturing and repair facilities to obtain exceptional payoffs in manufacturing cost and cycle-time and to enable faster surge capabilities to benefit the entire defense manufacturing base. Operational C-17 and F-15 aircraft were experiencing excessive downtimes due to inefficient maintenance processes, so LAI subsequently conducted a number of Lean events. Significant cycle-time and cost reductions were experienced as a result of LAI to include the following examples: a $6.5B acquisition cost savings on the C-17 and cycle time reductions at Warner Robins ALC that have put the equivalent of an extra squadron of F-15s into the hands of the Warfighter rather than on the ground waiting for repair. Conducted from 1998 to present, LAI participants include the Army, Navy, Air Force, Defense Acquisition University, Defense Contract Management Agency, the Institute for Defense Analysis, National Air and Space Administration, and OSD. Non-federal participants include twenty-five aerospace companies and the Massachusetts Institute of Technology (Cambridge, MA). The LAI program received Air Force ManTech funding of $21.31M through FY07. Other DoD funding used to co-develop Lean practices to date is $4.727M. Industry cost sharing funds were provided in the amount of $16.6M total.

5.1.2 Lean Concepts for Production Ramp-up for Joint Direct Attack Munition

Surge in Joint Direct Attack Munition (JDAM) requirements caused a nine-fold increase in demand of munitions during Operation Iraqi Freedom. Lean concepts were applied

to the Honeywell MEMS IMU production line to enable surge production from 300 to 2,800 Joint Direct Attack Munition (JDAM) "smart bomb" kits per month at the end of 2003. The JDAM Demand Pull Supply Pilot (DPSP) Surge Manufacturing Program put Lean practices in place at key small and medium JDAM suppliers to eliminate schedule slips, increases in unit cost, or any loss in quality. This project was conducted from April 2000 – April 2004, and participants included the Air Force ManTech program office, JDAM Program Office, Boeing (St. Louis, MO), TechSolve (Cincinnati, OH), Honeywell (Minneapolis, MN), Enser (Pinellas Park, FL), CE Precision Assemblies (Chandler, AZ), Woven Electronics (Mauldin, SC), Stremel Corporation (Minneapolis, MN), Plastics Research Corporation (Ontario, CA), Precise Machining (Tulsa, OK), Hyatt Die Cast (Sunnyvale, CA) and Entwistle (Danville, VA). The total Air Force ManTech funding was $2.676M. Industry cost share was provided in the amount of $2.677M. As a result of the DPSP, there has been a $15M capital investment cost avoidance to date. The participating suppliers averaged a 60% reduction in cycle-time and a 25% improvement in productivity. Overall, a ten-fold production surge capacity was realized for JDAM.

5.1.3 Web-Based Six Sigma and Lean Manufacturing Process Tool for Small and Medium Enterprise Suppliers

A Lean manufacturing tool was first implemented in 2003 through the Air Force ManTech Small and Medium Enterprise Initiative (SMEI) Program. The program focused on the cost-effective delivery of Six Sigma and Lean manufacturing training to Small and Medium Enterprise (SME) Suppliers. Honeywell (Dallas, TX) successfully developed and demonstrated this Web-based Six Sigma and Lean Manufacturing training and application assistance tool to aid SME suppliers in implementing productivity improvements. As an example of the impact of the tool, one SME achieved a 3% reduction in the price of manufacturing an F-15 fighter aircraft component by using the tool. It was well-received by twenty-nine suppliers who participated in the SMEI program. Over 50 Six-Sigma/Lean Manufacturing 'quick hitter' improvement projects were implemented. The ManTech SMEI program was conducted from 2000 to 2003. The total Air Force ManTech funding was $1.363M. Additional DoD funds in the amount of $60K (prior to FY03) were also provided.

5.1.4 Lean Improvements to the DLA Industrial Plant Equipment Activity

The DLA Industrial Plant Equipment (IPE) activity supplies the machine tools for DoD maintenance facilities world-wide to include shipyards, air logistics centers, bases, and depot maintenance facilities. The DLA IPE activity was experiencing consistent problems associated with schedule delays and budget over-runs in their repair and overhaul operations. In 2005, DLA applied Lean manufacturing principles to the entire equipment rebuild process. These principles were developed under the DLA *Customer Value Industrial Plant Equipment Program*. Results included eliminating manufacturing waste, instituting visible and capable manufacturing processes, and reducing processing time. The program resulted in a much more compact layout of the repair facility that cut space needs by one-third, new processes for ordering parts and tracking status, and new painting and finishing processes for rebuilt machines. The total DLA ManTech funding was $4.8M. The total cost avoidance is $10.8M (through FY15).

5.2 Troop Support Manufacturing Technology Implementations

5.2.1 Combat Rations Supply Chain Process Improvements

The combat rations industrial base is very small, and military specifications preclude the use of most commercially-available products. DLA's *Combat Rations Network for Technology (CORANET)* Program was developed to introduce new technologies and process improvements in the combat rations industrial base. CORANET is a community-of-practice, which includes all military and federal organizations involved in combat rations, multiple university research partners, and the combat ration manufacturers themselves. The major objectives of this program are accomplishing short-term projects that ensure surge production capability, maintain food safety, improving the quality and producibility of combat rations, and/or help make combat rations affordable. As a result of the CORANET program, the DoD made extensive improvements to Meals, Ready-to-Eat (MREs) and unitized group rations since its inception. Specific examples of technologies and processes implemented in 2006 to 2007 that were funded in the FY03-FY05 timeframe include:

- Quality improvement techniques were applied to improve the formulations of MRE cheese spread, thereby reducing discoloration and improving shelf-life.
- Ultra High Pressure Processing was used to process and formulate MRE egg entrees. Field testing indicated greater soldier acceptance of these egg products.
- Nondestructive seal testing equipment and ultrasonic sealing equipment were demonstrated within the industrial base, to decrease seal defects and reduce waste.
- An improved retort rack molding material was developed that will last longer, allowing for greater surge capability. It will also reduce retort handler injury.

The CORANET program began in FY99 and has continued through FY08. Program participants in addition to DLA include; the Army Center of Excellence, Subsistence, the Army Veterinary Command, the Department of Agriculture; the U.S. Marine Corps, and the Army Natick Soldier Research (RDECOM). The total DLA ManTech funding to date is $25.341M (FY96 to FY08), and the industrial ration providers have provided cost sharing funds that total $3.8M. It is expected there will be a total cost avoidance of $43M.

5.2.2 Military Apparel Manufacturing Supply Chain Process Improvements

The domestic military apparel manufacturers are under-capitalized and are in need of many improvements within their supply chain. The DLA *Apparel Research Network (ARN)* Program was initiated in 1995 for the purpose of modernizing the ordering, distribution, and manufacturing of military uniforms through the use of advanced technology for better uniform fit, and reduced logistics response time through electronic order generation and processing to clothing manufacturers. DLA's Defense Supply Center Philadelphia (DSCP) personnel, 8 of 9 military service recruit depots, and the vast majority of military apparel manufacturers have fully implemented recruit clothing supply chain improvements and new recruit clothing process technologies. Specific accomplishments that were funded during FY95 – FY03 and implemented through FY03 - FY05 and beyond included:

- Three-dimensional (3-D) Body Scanning, which mitigates the problem of poor and/or time-consuming manual sizing at recruit depots.

- An Asset Visibility System, which acts as a single information hub for supply chain managers. This system provides near real-time visibility across the supply chain of apparel assets.

- A Decision Support System, which minimizes system-wide costs by balancing inventories and creating a flow of order information and products throughout the supply chain, to include manufacturers.

- Improved Web-based applications for manufacturers, which enables electronic transmission of orders, processing, and invoicing.

The ARN program project duration was from FY95 – FY03. Program participants included DLA, U.S. Marine Corps Recruit Depots, Product Data Integration Technologies, Inc.(CA) , AdvanTech, Inc.(MD), Clemson University (SC), Cyberware (CA), Cal Tech (CA), and the IIT Research Institute (IL). The total DLA ManTech funding from FY03-FY04 was $8M. There was a total cost avoidance of $83.6M in lower inventory savings through better asset visibility, as a result of this investment.

5.3 Advanced Manufacturing Technology for Depots

5.3.1 Network Centric Manufacturing for FCS and Bradley Fighting Vehicle

Few Army weapons systems have utilized network centric manufacturing in their early design and repair activities. CAD and manufacturing tools, particularly at the supplier level, are often incompatible. This Army ManTech project, *Manufacturing for Structural and Overlay Armor,* implemented processing of composite armor solutions and network centric manufacturing tools. A modeling and simulation environment was created where CAD information from Pro-E – being used by the Future Combat System Vehicle Integrators – can interact with the Production Processes Resource Hubs and Delmia computer-aided manufacturing tools. At Red River Army Depot, this process was used to transform paper work instructions for the Bradley transmission into audio-video interleave-based work instructions. To date, over 2,300 vehicle transmission parts at the Depot have been processed through these model-based manufacturing tools. The duration of this project is July 2003 - September 2011, and participants include the Army RDECOM, Army Research Lab, NIST (Gaithersburg, MD) and BAE (York, PA). The total Army ManTech funding (FY03 – FY08) is $36.9M. This program projects a net total cost avoidance of $327M from full rate production of FCS.

Future Combat Systems (FCS) Command and Control Vehicle

5.3.2 Multi-Axis Platform for Improved Aircraft Access, Maintenance and De-paint

Aircraft tied up in extended depot maintenance create unacceptable mission capable rates. To address this problem, the Air Force implemented a radically new type of aerial platform for aircraft access, maintenance, and de-painting operations. Two types of aerial multi-axis platforms (AMPs) have been installed: one at OC-ALC for aircraft access, maintenance, and replacement of aircraft components, and a second type at WR-ALC for large cargo aircraft de-painting operations. The OC-ALC AMP platform features a hoist capability that was first used to attach multiple aircraft control surfaces to a KC-135 in February 2007. This enhanced

maintenance system significantly improved the user's control of the aircraft part being replaced allowing a 70-100% reduction in operator injury. By the end of FY08, four complete de-painting AMP systems will be installed at WR-ALC in the new large aircraft de-paint hanger. It is estimated there will be a 40-50% reduction in de-paint flow time. Overall, it is estimated there will be a 20% reduction in costs associated with production paint stripping on large cargo aircraft. The duration of this project is from May 2001 – October 2008, and participants include the Air Force ManTech Program, the National Institute of Standards and Technology (NIST) and the U.S. Technology Aerospace Engineering Corporation (Byron, GA). The total Air Force ManTech funding is $7.49M. Other DoD funding was provided in the amount of $6.685M. Industry provided cost share funds in the amount of $1.7M. It is projected there will be $8M cost avoidance per year along with the benefit of returning high value aircraft to operational duty sooner due to faster and improved depot maintenance with the AMP.

5.4 ENERGETICS AND MUNITIONS

5.4.1 Improved Manufacturing Processes for High-Rate Fuze Production

High rate production ramp-up for the Joint Programmable Fuze (JPF) Program required lean system concepts. The contractor had previously been unable to produce fuzes that met Air Force requirements. In April 2003, the Air Force ManTech office and the Direct Attack Systems Group at Eglin AFB, FL began work with Kaman Fuzing (Orlando, FL) and TechSolve (Cincinnati, OH) to implement manufacturing improvements to meet the aggressive production rates demanded by the Warfighter. A Kanban system was subsequently implemented, establishing a steady supply of raw materials for the fuzes. The operators and manufacturing engineers worked with the Air Force to list 140 manufacturing process steps and identified and eliminated the root causes of workmanship defects. The duration of this project is from April 2003 to September 2008. The total Air Force ManTech funding was $2.062M. Kaman Fuzing provided $363K to transition the Lean concepts into the production line by September 2008. This ManTech effort enabled Kaman Fuzing to pass the Air Force's first article acceptance test, achieve production readiness for low rate initial production, and ramp-up production to more than 500 fuzes per month.

5.4.2 Alternative Processes for Insensitive Munitions Manufacturing

The DoD requires insensitive munitions development for safer Warfighter systems. Triamino-trinitrobenzene (TATB) is one of the least sensitive explosive materials known and is a critical ingredient in the booster explosive PBXN-7 which is used in Navy bombs and missiles. Environmental issues had caused all U.S. sources for TATB to cease manufacturing. This project successfully developed a flexible, agile, and environmentally-friendly domestic production scale TATB manufacturing capability. The technology was implemented at ATK Launch Systems during the second quarter of 2006. The project duration was from November 2000 – January 2007. Participants included the Energetics Manufacturing Technology Center (EMTC) at the Naval Surface Weapons Center - Indian Head Division (Indian Head, MD) and ATK Launch Systems (Brigham City, UT). The customers are PEO (Weapons) and PMA 201 (Conventional Strike Weapons - Fuzes). The Navy and other DoD Program Offices now have multiple procurement options for acquiring TATB explosive to support fuze programs such as the FMU-139 bomb fuze, the FMU-143, the FMU-152 Joint Programmable Fuze, and to support fuze boosters for missile programs such as the Tomahawk Land Attack Missile (TLAM) and the Stand-off Land Attack Missile Expanded Response (SLAM-ER). The total Navy ManTech funding was $3M. In

addition, the Air Force and PMA 201 provided $1.2M for qualification testing. ATK Launch Systems contributed $0.2M for facility modifications.

5.4.3 Low Cost, Reliable Packaging for Miniaturized Explosive Components

Miniaturized explosive components have historically been expensive and unreliable. The Naval Surface Warfare Center, Indian Head Division developed and demonstrated safe and arm (S&A) packaging processes. The result is a lower cost, improved quality, reliable miniaturized initiator. The processes were implemented into the Common Very Light-Weight Torpedo (CVLWT) engineering development model in 2005 and will be fully transitioned to the warhead manufacturer at the end of system design and development. This project was conducted from January 2001- March 2005, and participants included the EMTC at the Naval Surface Weapons Center Indian Head Division (Indian Head, MD), Honeywell (Kansas City, MO) and PCB/Electronics (Raleigh, NC). The Navy ManTech investment totaled $1.1M. The Undersea Defensive Warfare Systems Program Office (PMS 415) provided $675K for the process development. Honeywell provided a $55K cost share. The cost of the initiator was reduced from $2000 each to an estimated $350 each. At two initiators per CVLWT and 8 CVLWTs per surface ship, the estimated cost avoidance is $4.2M.

6 CONCLUSION

The ManTech Program implemented technologies and processes that have resulted in a significant impact on weapons systems affordability, deployment of key Warfighter capabilities, and effective transition of technology. From FY03 to FY05, the overall investment of the Army, Navy, Air Force, and DLA ManTech Programs was $705M. As a result, there are over 100 implementations of manufacturing technologies and processes. Although system acquisition schedules slip and production quantities change, the estimated impact of these implementations, as reported, are projected at over $6.3B. ManTech has demonstrated tremendous return on investment – a tenet corroborated by the Defense Science Board in its 2006 report on Manufacturing Technology: A Key to Affordably Equipping the Future Force.

ManTech demonstrated a significant impact on major weapons systems affordability. Army ManTech was the centerpiece of affordability for hybrid electric power components and armament systems of the Army Future Combat Systems. The Air Force ManTech metals affordability and propulsion initiatives had a major impact on aircraft engine affordability in the areas of the F100 and F110 engines. The Navy shipbuilding sector, in particular aircraft carriers and submarines, realized dramatic efficiencies in major system affordability. DLA investments in castings, electronics obsolescence and military apparel research reduced lead-time and sustainment costs for DoD.

Jointly-coordinated ManTech investments enabled the transition of key transformational technologies. ManTech investments in MEMS technologies led to higher-yield production of precision munitions such as the 155mm Excalibur artillery round. Implementation of MEMs technology in the Excalibur provided a new Warfighter capability for precision artillery delivery in urban environments with less collateral damage that was deployed in Iraq and Afghanistan. Another jointly-coordinated effort conducted during the same timeframe as MEMS was in the area of Focal Plane Arrays. Implementation of advanced cooled and uncooled focal plane array technologies in sensor systems put improved vision systems into the hands of the Warfighter. ManTech improved performance of these systems and provided higher production rates that helped meet surge requirements.

ManTech effectively leveraged commercial tools, processes and cost sharing to strengthen the defense manufacturing capabilities and to assure technologies transfer to key suppliers. ManTech also worked closely with industry partners to increase manufacturing readiness, enable early production and address environmental requirements, for example, in the areas of night vision goggles, C-17 composite doors and lead-free soldering. Overall, improved industrial base responsiveness and implementation of Lean processes resulted in faster depot processing, facilitated dual-use technologies, and assured reliable domestic suppliers.

ManTech continues its joint coordination with the ManTech community – the Services, Agencies, and industry – to gain a perspective on overall manufacturing investments in order to obtain a diverse and balanced portfolio to affordably meet the future defense manufacturing needs of the United States.

APPENDIX A – SUMMARY OF TYPE OF MANTECH IMPLEMENTATIONS

2.0 Electronics Technologies and Processes

2.1 Electronics – Packaging, Assembly, and Obsolescence

TECHNOLOGY OR PROCESS IMPLEMENTED	SPONSOR	DEFENSE MATERIEL MFR	PROGRAM OF RECORD	COMMERCIAL ITEM MFR
MEMS IMUs for High-G, High Accuracy in Small Precision Missiles and Munitions Army Applications	Army	X	X	
MEMS IMUS for Precision Guidance in Navy Munition Applications	Navy-EMPF	X		
MEMS IMUs for Air Force Missile and Munition Applications	Air Force	X	X	
MEMS Implementation on Fuze Safe-and-Arm Devices	Army		X	
Affordable Ferroelectric and MEMS-Based Phase Shifters for Phased Arrays	Army		X	
Bump Attachment Process to Enable MIMIC Flip-Chip Technology	Navy-EMPF	X		
Masking and Demasking Process Improvements for the Active Electronically Scanned Array (AESA) Radar	Air Force	X	X	
Hermetic Sealing of SiC Wafers for T/R Modules on Phased Array Radars	Navy-EMPF	X		
Flexible Display Manufacturing Technology for Soldiers	Army	X		
Improved Processes Result in Reduced Costs for Large Aircraft Infrared Countermeasures (LAIRCM) System	Air Force	X	X	
Improved High Voltage Packaging to Reduce Weight and Improve Reliability	Navy-EMPF	X	X	
Lead-Free Manufacturing Guidelines for the F/A-18	Navy-EMPF		X	
Improved Output Traveling Wave Tube Manufacturing Processes	Navy-EMPF	X		

TECHNOLOGY OR PROCESS IMPLEMENTED	SPONSOR	DEFENSE MATERIEL MFR	PROGRAM OF RECORD	COMMERCIAL ITEM MFR
Improved Surge Capability for Night Vision Goggle Intensifier Tubes	Air Force	X		
Improved Manufacturing Processes for Helmet-Mounted Display Visors	Navy-EOC	X		
New Littoral Combat Ship (LCS) Flexible Antenna System to Reduce Interference Problems	Navy-EMPF		X	
Processes and Tools to Predict and Manage Electronic Parts Obsolescence	Air Force	X		X

2.2 Electronics – Electro-Optics

TECHNOLOGY OR PROCESS IMPLEMENTED	SPONSOR	DEFENSE MATERIEL MFR	PROGRAM OF RECORD	COMMERCIAL ITEM MFR
Improved Yield and Advanced Fabrication Technology for Night Vision Systems	Army	X		
Two-Color Mid-Wave IRFPAs to Increase Warfighter Survivability	Navy-EOC	X		
Large Scale Wafers to Reduce Costs of JSF Infrared Focal Plane Arrays	Air Force	X	X	
Manufacturing Improvements to Reduce Cost of Dual Band Focal Plane Array	Army		X	
Reduced Cost Manufacturing and Improved Large Spinel Windows for JSF	Air Force	X	X	
Low Cost Fiber Optics Tether Increases Bandwidth on MK48 Torpedo	Navy-EOC		X	
New Fiber Optic Array Splice Manufacturing Process for Undersea Array Cables	Navy-EOC	X		
Automated Fiber Optic Interconnect Technology Process	Navy-EOC	X		
Alternate Remote Shipboard Lighting for Reduced Costs	Navy-EOC	X		
ManTech for Military Lasers	Army	X		

2.3 Electronics – Power

TECHNOLOGY OR PROCESS IMPLEMENTED	SPONSOR	DEFENSE MATERIEL MFR	PROGRAM OF RECORD	COMMERCIAL ITEM MFR
New Energy Storage System for SEAL Delivery Vehicle	Navy-EMPF	X		
Automated Production Line for Very High Power FCS Batteries	Army	X	X	X
SiC Power Electronics Manufacturing for FCS	Army		X	
Thermal Battery Development and Fielding	Navy-EMPF	X		

3.0 Metals Technologies and Processes

3.1 Metals - Processing

Uniform Cannon Tube Reshaping Process	Army	X	X	
Metals Affordability Initiative – Improved Manufacturing Processes and Accelerated Production of Metallic Components for Aircraft Structures and Engines	Army Navy Air Force	X	X	X
Advanced Bonding Methods and Coatings for Steel Structures	Navy	X		
Collaborative Tools and Technologies to Support the Forging Industrial Base	DLA	X	X	
NCDMM Products to Support Rapid Response Needs	Army	X		
Laser Shock Peening Surface Treatment for Increased Durability of Army and AF Propulsion Systems	Air Force Army	X	X	X
Hot Section Coating Protection Technology for DDG 51 Gas Turbine Engine	Navy-iMAST	X		
Isotropic Super Finishing for Power Transfer Systems	Army	X	X	X
Improved Magnesium Protection Process for Army Helicopters	Army	X	X	X

TECHNOLOGY OR PROCESS IMPLEMENTED	SPONSOR	DEFENSE MATERIEL MFR	PROGRAM OF RECORD	COMMERCIAL ITEM MFR
Castings Process Improvements to Sustain Legacy Weapons Systems	DLA	X	X	
Reconfigurable Tooling Technology for Overhaul and Repair of Aging Subsystems	Air Force	X		
Single-Melt Process for Titanium in Lightweight Armament and Ground Vehicles	Army	X	X	
Applications Development for Use of Laser Beam Welded Corrugated Core Panels	Navy-NMC	X		
High Strength Marine Grade Fasteners	Navy-NMC	X		
Advanced Thermal Battery Case Production	Navy-NMC	X		
Propulsor for Seawolf Class Submarine	Navy-iMAST	X		
Long Life Non-Skid Coatings for CVN	Navy-iMAST	X		
Brush Electroplating for Repair of Metal Components	Navy-iMAST	X		
Polycan Fabrication Improvements	Navy-iMAST	X	X	
Helicopter Blade Refurbishment	Navy-iMAST	X		
Vertical Launch System (VLS) Tube Repair	Navy-iMAST	X		

3.2 Metals - Joining

Availability of Shielded Metal Arc Welding Electrodes for Ballistic Performance Requirements	Navy-NMC	X	X	
Low-Cost Friction Stir Welding of Aluminum for LCS Applications	Navy-NMC	X		
Virtual Training for Welding	Navy-NJC		X	X
Translational Friction Welding of Titanium Engine Blisks	Navy-NJC		X	X

TECHNOLOGY OR PROCESS IMPLEMENTED	SPONSOR	DEFENSE MATERIEL MFR	PROGRAM OF RECORD	COMMERCIAL ITEM MFR
Manufacturing Large Marine Structures	Navy-NJC/NMC	X	X	
Implementation of Weld Process Control in Shipbuilding	Navy-NJC	X		
Weld Distortion and Accuracy Control	Navy-NJC	X		
Elimination of Heavy Plate Weld Distortion on CVN 21 Erection Units	Navy-NMC	X	X	
Ultra-light Welding System	Navy-CNST	X		
Welding Training and Data Collection	Navy-CNST	X		
Implementing High-Strength, Low Weight Steel on CVN 78	Navy-NJC	X	X	
Improved Welding and Forming Practices for HSLA-65 Materials for CVN 21	Navy-NMC	X		
Affordable Titanium Howitzer Components	Navy-NMC	X	X	
Titanium Howitzer Welding	Navy-NJC	X		
Steel Investment Castings for Howitzer	Navy-NMC	X		
Reduced Cost Titanium Alloy for Howitzer	Navy-NMC	X		

3.3 Metals – Modeling and Simulation

Modeling and Simulation for Carrier Construction Planning and Sequencing	Navy-iMAST		X	
Manufacturing Process Modeling and Fabrication for DDG 1000	Navy-iMAST	X		
DDG 1000 Decision Support System for Lead Time Reduction	Navy-iMAST		X	
Reduced VIRGINIA Class Submarine Cost Drivers	Navy-iMAST		X	
Predictive Weld Distortion Techniques	Navy-CNST	X		

TECHNOLOGY OR PROCESS IMPLEMENTED	SPONSOR	DEFENSE MATERIEL MFR	PROGRAM OF RECORD	COMMERCIAL ITEM MFR
Material Workflow Process Improvement for Shipyards	Navy-CNST	X		
VIRGINIA Class Submarine (VCS) Design Techniques	Navy-iMAST	X		
Flexible Fixtures to Support Product-Centered Structural Fabrication	Navy-NJC	X		

3.4 Metals - Inspection and Test

Non-Destructive Inspection Techniques for F100 and F110 Engine Components	Air Force	X		
Submarine Alignments and Inspections	Navy-iMAST	X	X	
Gear Metrology and Performance Prediction	Navy-iMAST	X		

4.0 Composites Technologies and Processes

4.1 Composites and Lightweight Material

Composites Affordability Initiative: Technologies and Tools for Manufacture of Lower Cost, Large Integrated and Bonded Composite Structures	Air Force	X	X	X
Composite Overwrap Process for Light Weight Cannons	Army		X	
Low Cost Lightweight Helicopter Structures	Army		X	
Extended Life Propulsion Shaft Surface Treatment	Navy-CMTC	X		
Integrated Bleeding Fabrication Process for VIRGINIA Class Submarines	Navy-CMTC	X		
Composite Processes for Expeditionary Fighting Vehicle Troop Ramp Door	Navy-CMTC	X		
New Composite Manufacturing Technology Process for Marine Impeller	Navy-CMTC	X		

TECHNOLOGY OR PROCESS IMPLEMENTED	SPONSOR	DEFENSE MATERIEL MFR	PROGRAM OF RECORD	COMMERCIAL ITEM MFR
Improved Fabrication Technology for the Advanced Seal Delivery System Stator	Navy-CMTC	X		
Advanced Electric Ship Demonstrator Deckhouse (AESD)	Navy-CMTC	X		
Alternate High Frequency Material to Replace Tape Covering Access Panel Gaps and Fasteners on B-2 Aircraft	Air Force	X	X	

5.0 Other Manufacturing Technologies and Processes

5.1 Lean Manufacturing

Lean Manufacturing Processes for C-17 and F-15	Air Force	X		X
Lean Concepts for Production Ramp-up for Joint Direct Attack Munition	Air Force	X	X	
Web-Based Six Sigma and Lean Manufacturing Process Tool for Small and Medium Enterprise Suppliers	Air Force	X		
Lean Improvements to the DLA Industrial Plant Equipment (IPE) Activity	DLA	X	X	

5.2 Troop Support Manufacturing Technology Implementations

Combat Rations Supply Chain Process Improvements	DLA	X	X	
Military Apparel Manufacturing Supply Chain Process Improvements	DLA	X	X	

5.3 Advanced Manufacturing Technology for Depots

Network Centric Manufacturing for FCS and Bradley Fighting Vehicle	Army	X	X	
Multi-Axis Platform for Improved Aircraft Access, Maintenance and De-paint	Air Force	X		

5.4 Energetics and Munitions

TECHNOLOGY OR PROCESS IMPLEMENTED	SPONSOR	DEFENSE MATERIEL MFR	PROGRAM OF RECORD	COMMERCIAL ITEM MFR
Improved Manufacturing Processes for High-Rate Fuze Production	Air Force	X	X	
Alternative Process for Insensitive Munitions Manufacturing	Navy-EMTC	X		
Low Cost, Reliable Packaging for Miniaturized Explosive Components	Navy-EMTC	X		

APPENDIX B - ACRONYM LIST

ACRONYM	DEFINITION
A&I	Alignment and Inspection
ADCAP	Advanced Capability
AESA	Active Electronically Scanned Array
AESD	Advanced Electric Ship Demonstrator
AFRL	Air Force Research Lab
AFS	American Foundry Society
AGM	Air-to-Ground Missile
AGS-LRLAP	Advanced Gun System and Long Range Land Attack Projectile
AHFM	Alternate High Frequency Material
AIT	Automatic Identification Technology
AMRDEC	Aviation and Missile Research, Development and Engineering Center
AMC	American Metalcasting Consortium
AMCOM	Aviation and Missile Command (Army)
AMP	Aerial Multi-Axis Platform
ARDEC	Armaments Research, Development and Engineering Center
ARL	Army Research Laboratory
ARN	Apparel Research Network
AS&C	Advanced Systems and Concepts
ASDS	Advanced Seal Delivery System
ATI	Advanced Technology Institute
ATO-M	Advanced Technology Objective – Manufacturing
ATP	Advanced Targeting Pod
CAD	Computer Aided Design
CAI	Composites Affordability Initiative
CAPRI	Controlled Atmospheric Pressure Resin Infusion
CAST-IT	Casting Advanced Systems Technology Integration Team
CERDEC	Communications-Electronics Research, Development and Engineering Center
CNC	Computer Numerical Control
CNST	Center for Naval Shipbuilding Technology
COM	Center for Optics Manufacturing
COE	Center of Excellence
CORANET	Combat Rations Network for Technology
COTS	Commercial Off The Shelf

CS	Combat Systems
CVLWT	Common Very Light-Weight Torpedo
CVN	Carrier Vessel Nuclear
DARPA	Defense Advanced Projects Agency
DDR&E	Director Defense Research and Engineering
DHS	Department of Homeland Security
DLA	Defense Logistics Agency
DoC	Department of Commerce
DoD	Department of Defense
DoE	Department of Energy
DPSP	Demand Pull Supply Pilot
DSCP	Defense Supply Center Philadelphia
DSCR	Defense Supply Center Richmond
DSS	Decision Support System
DTO	Defense Technology Objective
EFV	Expeditionary Fighting Vehicle
EGBU	Enhanced Guided Bomb Unit
EM	Electro-magnetic
EMPF	Electronics Manufacturing Productivity Facility (Navy)
EMTC	Energetics Manufacturing Technology Center
EPOI	Electronics Parts Obsolescence Initiative
ERGM	Extended Range Guided Munitions
ERLE	Engine Rotor Life Extension
FAP	Final Assembly Platen
FCS	Future Combat System
FDMC	Forging Defense Manufacturing Consortium
FLIR	Forward Looking Infrared
FPA	Focal Plane Array
FRC	Fleet Readiness Center
FSW	Friction Stir Welding
FTWQ	First Time Weld Quality
GAM	GPS-Aided Munition
GDEB	General Dynamics Electric Boat
GDLS	General Dynamics Land Systems
GEAE	General Electric Aircraft Engines
GMAW	Gas Metal Arc Welding
HMDV	Helmet-Mounted Display Visor

HMMWV	High Mobility Multipurpose Wheeled Vehicle
HUD	Head-up Display
IDECM	Integrated Defensive Electronic Countermeasures
IM	Insensitive Munition
iMAST	Institute for Manufacturing and Sustainment Technologies (Navy)
IMU	Inertial Measurement Unit
IPE	Industrial Plant Equipment
IPNVG	Integrated Panoramic Night Vision Goggles
IRFPA	Advanced Infrared Focal Plane Array
IR	Infrared
IRR	Internal Rate of Return
ISF	Isotropic Super Finishing
JASSM	Joint Air-to-Surface Standoff Missile
JDAM	Joint Direct Attack Munition
JDMTP	Joint Defense Manufacturing Technology Panel
JPF	Joint Programmable Fuze
JSF	Joint Strike Fighter
JUMPED	Joint Ultimate Manufacturing Process Evolution and Development
LAI	Lean Advancement Initiative
LAIRCM	Large Aircraft Infrared Countermeasures
LAM	Laser Additive Manufacturing
LASCOR	Laser Beam Welded Corrugated Core
LCS	Littoral Combat Ship
LENS	Laser-Engineered Net Shaping
LRAS3	Long Range Advanced Scout Surveillance System
LSP	Laser Shock Peening
MAI	Metals Affordability Initiative
MALD	Miniature Air Launched Decoy
MAS	Maneuver Ammunition Systems
ManTech	Manufacturing Technology
MCPP	Magnesium Corrosion Protection Program
MDA	Missile Defense Agency
MEMS	Micro Electro-Mechanical System
MIDS	Modular Isolated Deck Structure
MRE	Meals Ready to Eat
MRF	Magnetorheological-Finishing
MRL	Manufacturing Readiness Level

NADCA	North American Die Casting Association
NAVAIR	Naval Air Systems Command
NAVSEA	Naval Sea Systems Command
NCDMM	National Center for Defense Manufacturing and Machining
NFFS	Non-Ferrous Foundry Society
NFTD	National Forging Tooling Database
NGS	Northrop Grumman Shipbuilding
NIST	National Institute of Standards and Technology
NJC	Navy Joining Center (Navy)
NLOS	Non Line Of Sight
NLOS-C	Non-Line-of-Sight Cannon
NMC	Navy Metalworking Center
NPV	Net Present Value
NSF	National Science Foundation
NSN	National Stock Number
NSW	Naval Special Warfare
NUWC	Naval Undersea Warfare Center
NSWCCD	Naval Surface Warfare Center Carderock Division
O&S	Operations and Support
OC-ALC	Oklahoma City Air Logistics Center
ODUSD	Office of the Deputy under Secretary of Defense
OEM	Original Equipment Manufacturer
ONR	Office of Naval Research
OSD	Office of the Secretary of Defense
OSI	Ordinance Systems Incorporated
OTWT	Output Traveling Wave Tubes
PAM	Precision Attack Missile
PDA	Personal Data Assistant
PEO	Program Executive Office
PFAST	Production Flow Analysis Simplification Toolkit
PHNSY	Pearl Harbor Naval Shipyard
PM	Program Manager
POM	Program Objectives Memorandum
PRO-ACT	Procurement Readiness Optimization – Advanced Casting Technology
PRO-FAST	Procurement Readiness Optimization - Forging Advanced Systems Technology

PVLS	Peripheral Vertical Launching System
RDECOM	Research, Development and Engineering Command
RF	Radio Frequency
RFID	Radio Frequency Identification
ROI	Return On Investment
RSL	Remote Source Lighting
RTIP	Radar Technology Insertion Program
S&A	Safe-and-Arm
S&T	Science and Technology
SBIR	Small Business Innovative Research
SDD	Systems Development and Demonstration
SDV	Seal Delivery Vehicle
SFSA	Steel Founders Society of America
SLAM-ER	Stand-off Land Attack Missile Expanded Response
SLAMRAAM	Surface Launched Advanced Medium Range Air to Air Missile
SMAW	Shielded Metal Arc Welding
SME	Small and Medium Enterprise
SMEI	Small and Medium Enterprise Initiative
SOCOM	Special Operations Command
SPC	Statistical Process Control
TACOM LCMC	TACOM Life Cycle Management Command
TARDEC	Tank and Automotive Research, Development and Engineering Command
TATB	Triamino-trinitrobenzene
TDS	Traction Drive System
TFW	Translational Friction Welding
TLAM	Tomahawk Land Attack Missile
T/R	Transmit / Receive
VCS	VIRGINIA Class Submarine
VLS	Vertical Launch System
VPV	Virtual Prime Vendor
WBG	Wide Band-Gap
WCMD	Wind-Corrected Munitions Dispenser
WR-ALC	Warner Robins Air Logistics Center